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In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and x rays, and fallout. The Department delegated this responsibility to the Bureau of Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the Bureau of Radiological Health by Federal agencies, State health departments, universities, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.

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Technical Note

Environmental Surveillance Around Nuclear Power Reactors

Joseph A. Lieberman,[1] *Ernest D. Harward,*[2] and *Charles L. Weaver*[3]

Experience gained over the past several years by the Bureau of Radiological Health and by various States has provided a technical basis for the establishment of surveillance programs in the environs of nuclear plants. The guidance for environmental surveillance of nuclear facilities provided by the Bureau of Radiological Health for use by States is applicable to those areas external to the facility's site perimeter or fenced area, which are normally considered as the plant environs or offsite area. Accomplishment of the objectives of these programs assures the continuing examination and evaluation of the environment needed to insure the continued protection of the health and safety of the public.

The prime objectives of environmental surveillance programs for nuclear power stations are (1) to verify the adequacy of source control, (2) to provide data to estimate population exposure, and (3) to provide a source of data for public information. An environmental surveillance program obviously should be conducted by the facility operator and such a program is required by the Atomic Energy Commission (AEC) license. Some utility companies contract for these programs with commercial laboratories. As a minimum, surveillance activities by the State health agency should provide adequate verification of the facility's data. This procedure allows both the health agency and the operator to have confidence in the accuracy of the results. To assure compatibility of the surveillance data from both Federal and State programs, an Analytical Quality Control Service is available to the States through the Bureau's area laboratories.

The media to be sampled, the frequency of sampling, and the type of analysis needed are all dependent upon the specific objectives that have been established for the surveillance program at the facility by the State and the operator. The extent of surveillance required is dependent on the nuclear facility's location with reference to such factors as population density, meteorology, and other environmental considerations, and the quantities and kinds of radioactive materials discharged. Planning for the environmental surveillance program should include an evaluation of the critical radionuclides anticipated in the normal discharges and the pathways through which they may disperse in the environment and thus expose the population to radiation. Because air and water are pathways through which radioactive contaminants are carried to other segments of the environment, analysis of radioactivity in these media is a basic requirement in the establishment of a surveillance program. Further, an investigation of the site environs is necessary to identify the pathways of exposure and the members of the public most likely to be subjected to potential exposure. Exposure of this critical population group can result from direct external radiation and from intake of radioactive material into the body through ingestion and inhalation.

In initiating an environmental surveillance program (table 1), it is important that radiological measurements be made and data obtained through a preoperational survey of the plant environs. This survey should consider the critical nuclides, pathways, population groups, and any other information needed to design the operational program. Additional information and benefits will be obtained for other purposes, such as: (1) a data base to be used in identifying any radioactive material released to the environment by the plant after initial startup, (2) evaluation of the proposed operational surveillance system (3) training and experience for the personnel conducting the survey, and (4) a mechanism for gathering data for public information. Because waste discharges from a nuclear power plant operating under normal conditions may influence radioactivity levels only in a limited area of the environment, preoperational samples should be taken beyond the plant's influence for comparison with those taken near the site. This practice can be continued into the operating phase and a statistical comparison made in order to delineate possible contributions by the plant to environmental radioactivity levels. It has been normal practice for preoperational surveys to be conducted for a period of 1 year before the initial startup of a nuclear installation. In those cases where personnel are inexperienced in surveillance operations and laboratory analysis of samples or special requirements are indicated, a longer period of time may be necessary in order to obtain reliable data for at least 1 year.

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The data gathered by the environmental surveillance program during plant operation provides a basis for source control and estimation of population dose. Complete liquid and gaseous radioactivity discharge data should be routinely provided to the health agency by the operator so that the relationship between radioactive discharges and the environmental surveillance data can be established. Experience to date with nuclear power plants has shown that careful waste management and proper operating procedures generally result in radionuclide concentrations in waste effluents less than a few percent of the AEC's licensed discharge limits (*1–3*). It should be noted, however, that the large dilution capacity of condenser cooling water has been a significant factor in achieving these low effluent concentrations. Nuclear plants using cooling towers may not be able to reach such low concentrations because of the reduced volume of water discharged.

Detection of accidental releases from nuclear facilities is not an objective of a routine operational environmental surveillance program. The indication of the need for actions to protect the public or the environment must come from a facility operator immediately following any accidental release based on in-plant conditions and data and not several days or weeks later from routine environmental sampling. For this reason, adequate source monitoring and control must be in effect to detect immediately significant nonroutine releases of radioactivity. In the event of such a release, it is imperative that agencies responsible for public health be promptly notified so that they can initiate measures to protect the public, including emergency monitoring programs to ascertain what protective actions may be required. A special preplanned documented emergency monitoring system is required to provide the mechanism for assessing the public health hazard from an accidental release of radioactivity to the offsite area.

The recommended general program, shown in table 1 which has been published previously (*4, 5*), serves as a guide for the development of an environmental monitoring program, and is, in general, considered adequate from a public health standpoint. However, with the rapid expansion of the nuclear power industry, the number of individual facility monitoring programs will increase. Therefore, the Bureau of Radiological Health is reviewing these surveillance recommendations on the basis of field studies which are being carried out through several of the Bureau's laboratories to obtain information needed to determine whether these recommendations should be modified.

Because of the expansion of the nuclear power industry, it is important to have a coordinated nationwide surveillance program adequate to meet public health responsibilities for estimating population exposure. The Bureau of Radiological Health is proceeding with such a program as part of the Department's overall responsibility for evaluating environmental radiation from all sources. This program is being planned and developed with the cooperation and participation of State health agencies and the AEC. The objective of this effort is to provide a source of published data on environmental radioactivity levels associated with nuclear facilities which is readily available to the public and to the health and scientific community through the Bureau's monthly publication, *Radiological Health Data and Reports*. The implementa-

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Table 1. Typical environmental surveillance program for a nuclear power plant

Recommended Surveillance Program			
Vectors or indices	Relative frequency	Analyses	Sampling locations
Surface water: Receiving waters of the facility	Continuous composite or weekly grab	Gross beta and gamma scans. Periodic analysis for ^{3}H with frequency a function of the levels measured	Stream—above and below the facility; reservoir, bay, lake—nearest shoreline; any nearby domestic water suppliers using the receiving waters as a raw water source
Bottom sediments	Semiannually	Gross beta and gamma scans	Near reactor's outfall or above and below the outfall if the receiving water is a stream
Ground water	As applicable (usually quarterly or annually)	Gross beta and gamma scans	Supplies within 5 miles of the facility
Air: a) Inhalation	High-volume samples occasionally Low-volume samples daily or weekly	Gross beta and gamma scans of filters and cartridges	Populated areas within 5–15 miles of the facility
b) Immersion	Dosimeters changed monthly	Integrated dose due to noble gases by appropriate reader device	
Milk	Monthly	Gamma spectrum analysis for ^{131}I	Dairy herds within 10–15 miles of the facility
	Quarterly	^{89}Sr and ^{90}Sr or total Sr by beta analysis	Dairy herds within 10–15 miles of the facility
Aquatic biota	Variable	Gamma spectrum analysis for selected radionuclides	Near the reactor's outfall or above and below if receiving water is a stream
Food crops and other vegetation	Seasonal (before or at harvesting time)	Gamma spectrum analysis	Within a 10–15 mile radius of the facility
Soil	Annually	^{90}Sr and ^{137}Cs or gross beta	Prevailing downwind direction in nearest agricultural areas

tion of this activity will contribute substantially to meeting national objectives of protection of public health and preservation of environmental quality.

Bureau of Radiological Health field studies

The Bureau has conducted several field studies at operating nuclear facilities to obtain radioactivity data on which to base judgments on the surveillance required to better estimate population exposure. These studies have been conducted at a boiling water reactor, a pressurized water reactor, and a fuel reprocessing plant.

The first of these field studies was conducted at the Dresden Nuclear Power Station in Illinois during 1967 and 1968, by the Radiological Engineering Laboratory, Cincinnati, Ohio, in cooperation with the Illinois Department of Public Health, the Atomic Energy Commission, and the Commonwealth Edison Company. This site was selected because of the extensive operating experience with Dresden 1 and the development of other nuclear facilities at the same site. Dresden 1 has been in operation since 1962, and at the time of the study's inception, was the largest (200 MWe) operating boiling water reactor. The specific objectives of the study were to:

1. Develop better data on which to base guidance for environmental surveillance programs,
2. Obtain a more comprehensive knowledge of the problems associated with effluent monitoring from nuclear facilities,
3. Increase the depth of technical knowledge within the Bureau of Radiological Health in order to better assist States in developing surveillance programs, and
4. Evaluate the discharges of liquid and gaseous radioactivity and determine the critical pathways of specific radionuclides from the power plant through the environment to man.

Emphasis was placed on identifying critical pathways of radioactivity from source to man (table 2), including identification of any reconcentration media or indicator radionuclides within the pathways, and correlating stack discharges with the environmental radionuclide levels measured. Since the site will soon contain other reactors and a fuel reprocessing plant, the effect of multiple sources may be investigated at a later date.

Table 2. Sample types analyzed from the Dresden nuclear power station

In-plant	Plant discharges	Environs
Primary coolant	Discharge canal	Plume
Recycled demineralised water	Stack	Milk
Fuel pool water	(A) Gas	Cattle thyroids
Waste neutraliser tank	(B) Particulate filters	Rabbits
Laundry wastes	(C) Charcoal iodine filters	Corn kernels and husks
Delay line (off-gas)		Leafy vegetables
Containment building ventilation filters		Grass
Turbine building ventilation filters		Soil
		Drinking water
		Rain water
		Snow
		River water
		Silt
		Fish
		Deer

Various samples were collected at the Dresden Station for radionuclide analysis: (1) gas and particulates in the reactor discharge lines, (2) liquid wastes at various points within the plant waste systems, and (3) samples taken in the environment. This sampling procedure made it possible to determine the significant radionuclides in the plant before release and to correlate these known quantities discharged with any radionuclides detected in the environment. Critical radionuclides and their pathways through the environment that could cause significant exposure to man were identified. Techniques employed to measure radionuclides during the study were more sensitive than those normally used in routine environmental surveillance programs. This enabled a detailed quantitative evaluation of specific radionuclides to insure that all possible "critical" radionuclides were identified.

The final report for this field study has been published and is available to the public (*6*). The principal conclusions reached in this study can be summarized as follows:

1. The critical pathway for possible exposure of the population from this boiling water reactor was determined to be via the discharge of noble gases to the atmosphere. Based on survey instrument and dosimeter measurements around the site, the annual average whole-body exposure at the sampling locations during the study was estimated to range from 5 to 15 millirems per year. A more precise estimate was difficult because gaseous releases from Dresden resulted in environmental radiation levels which were only marginally above background.

2. Analysis of environmental samples from pathways to man other than the air pathway indicated either no detectable radioactivity as a result of operation of the plant or detectable levels too low to be considered significant in terms of population radiation exposure (table 3).

3. The population dose due to iodine-131 in the gaseous effluent was not measureable; stack discharge levels of iodine were small and this radionuclide was virtually undetectable in the environment.

In order to provide similar data on a pressurized water reactor, a study was conducted at the Yankee Atomic Power Station in Rowe, Mass. This study was just recently completed and the report is now in preparation (*7*). Preliminary data indicate that exposure in the environs from the discharge to the atmosphere of gaseous radioactive wastes from this reactor was not detectable. In addition, sampling of the aquatic environment did not reveal radioactivity levels that would produce measurable exposure to the public.

Table 3. Environmental samples[a]

Date	Radioactivity found in Dresden environs	Concentration
1/18/68	Snow (0.8 km from site in direction of plume)	10 pCi of strontium-90/liter
7/10/68	Cattle thyroids (2.3 km from site)	$\sim$0.5 pCi of iodine-131/g
8/20/68	Suspended solids from discharge canal	27 pCi of cobalt-60/g dried silt 11 pCi of cesium-137/g dried silt
8/21/68	Corn kernels (0.8 km from site)	4.0 pCi of cesium-137/g ash

[a] No radioactivity was found in soil, leafy vegetables, fish, grass, milk, rabbits, deer, drinking water (at Peoria), river water (at Peoria), or rain water, at the Dresden station.

A study by the Northeastern Radiological Health Laboratory is currently under way at the Nuclear Fuel Services, Inc., spent fuel reprocessing plant in western New York State. The objectives of this study are very similar to those discussed above for the nuclear power plants. Publication of the results of this study is planned for 1970.

Liquid waste discharges

Discharges of liquid radioactive wastes from nuclear power plants have been well below the limits specified by the AEC (*3*). A review of reported data has indicated that the type of reactor design (i.e., pressurized water or boiling water reactor) has had no apparent large-scale effect on the quantity or type of liquid wastes discharged to the environment except for tritium which is higher in pressurized water reactors. It is believed that proper in-plant waste management may be the most significant mechanism for the effective minimization of the quantity of radioactive wastes discharged. Thus, there are indications that levels of waste discharges are not necessarily a direct function of power levels.

The principal radionuclides found in liquid waste effluent during the boiling water reactor study, in order of decreasing percentage of 10CFR20 concentration limits, were determined to be iodine-131, strontium-90, strontium-89, cobalt-60, and cesium-137. In establishing a surveillance program for the water environment at an operating boiling water reactor plant, these radionuclides and their pathways to human exposure should be included.

Tritium in the environment

Tritium, a radionuclide resulting from nuclear plant operation, has recently been the focal point of attention. Although tritium is considered to be one of the less hazardous radionuclides, its continued production and release and relatively long radioactive half-life (12.3 years) will lead to increased levels in the environment as the number of nuclear power plants increases. Because tritium is an isotope of hydrogen, it can be metabolized in the form of tritiated water and incorporated into body fluids and tissues, although most of the tritium ingested would pass through the human body fairly rapidly with a biological half-life of about 10–12 days.

The mechanisms for production of tritium in nuclear reactors have been well documented (*8–10*). Data on tritium concentration levels in rivers on which nuclear facilities are located are routinely obtained by the Bureau of Radiological Health and the results periodically reported in *Radiological Health Data and Reports* (*11*). Surveillance of tritium in waters of the United States is now being expanded since the number of nuclear plants is increasing. Tritium concentrations measured in U.S. surface waters during 1967–1968 ranged from 200 to 8,400 pCi/liter. Calculated population exposure rates from continuous ingestion of water containing these concentrations would correspond to 0.03 to 1.4 mrem per year. By comparison the normal average population exposure rate from all natural sources of radioactivity is about 100–125 mrem per year.

The tritium currently found in the environment is largely due to fallout from previous atmospheric testing of nuclear weapons, and the levels are generally decreasing. Calculations made by the Bureau of Radiological Health indicate that tritium discharges from nuclear power plants now operating would have little if any detectable effect on tritium concentrations in the environment. Present tritium discharge levels are only a small fraction of presently accepted maximum permissible concentrations and on this basis do not constitute a significant hazard to public health. However, the anticipated growth of nuclear power with an increase in the number of both power reactors and fuel reprocessing plants will result in increased quantities of tritium being discharged into the environment. This potential source of population exposure will require continued monitoring and evaluation by public health agencies to insure that tritium in the environment does not reach levels of radiological health concern.

Gaseous waste discharges

As in the case of liquid wastes, gaseous discharges from operating nuclear power plants have generally been small fractions of the licensed limits. The principal radionuclides normally discharged, that are of public health interest, are the noble gases. Because of the differences in gaseous waste handling design between boiling

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water and pressurized water reactors, there are differences in the radionuclides contained in the effluents from the two kinds of plants. In most of the current boiling water reactor designs, gaseous wastes are discharged continuously following a delay time of approximately 30 minutes. Although relatively high total quantities of gaseous effluents are discharged, they have short half-lives and decay rather substantially before reaching offsite areas. The radionuclides normally contained in a boiling water reactor gaseous effluent would include isotopes of krypton and xenon with krypton-88, xenon-135, xenon-138, and krypton-87 predominating. It should be noted that boiling water reactors planned at three locations are to be equipped with gas holdup capacity which will further reduce offsite exposures. Pressurized water reactor waste treatment system designs incorporate a much longer storage time which allows for radioactive decay and these reactors discharge predominately krypton-85 with some xenon-133, although in very small total quantities. Offsite dose contributions from gaseous discharges have been undetectable in the case of an operating pressurized water reactor and only marginally above background for an operating boiling water reactor for those facilities studied by the Bureau.

Radioactive iodine is also a nuclide of public health concern because of the air-pasture-cow-milk chain which could permit concentration in a child's thyroid. Although it is of concern, these studies and a thorough review of surveillance data have not indicated iodine-131 to be of public health significance as a contaminant from normally operating nuclear power reactors. Iodine-131 was at relatively low concentrations in the gaseous effluent of the boiling water reactor studied and extensive efforts failed to detect this nuclide in environmental milk samples even with analytical techniques more sensitive than those employed in routine surveillance. Pressurized water reactor waste treatment systems normally eliminate iodine-131 through storage and decay because of its short radioactive half-life. During our field study of an operating pressurized water reactor, sampling in the environs failed to detect iodine.

Evaluation of surveillance data

Information from plant operating experience available over the past years has shown that nuclear power plants discharge relatively small quantities of radioactive wastes to the environment. The Bureau of Radiological Health has compiled both discharge and surveillance data obtained by plant operators and by State health agencies. In developing plans for a coordinated national surveillance program, consideration is being given to the publication of this type of data in a uniform manner in *Radiological Health Data and Reports*.

The recent Bureau studies at operating facilities, referred to earlier, confirmed that the discharge of radioactive effluents into the air and water environment has not produced radiation levels at these facilities that would result in radiation doses to the population sufficient to be of public health concern. The Bureau will, however, continue to assess all sources of environmental radiation to determine both short and long-term levels and make estimates of the radiation exposure to man.

The identification of the critical radionuclides and pathways for radionuclides to reach man generally requires that relatively few environmental media be analyzed in order to estimate population exposure from the operation of a nuclear power plant. For this reason, greater emphasis should be placed on conducting the facility environmental surveillance program utilizing a detailed knowledge of the effluent released. Studies have demonstrated that detailed analysis of the plant effluents can be quite meaningful, whereas, it is difficult to detect radioactivity in the environment that has resulted solely from plant operation. Field monitoring of radionuclides outside the plant boundary should be dependent on the level and kind of effluent released, although continuous monitoring of the critical pathway for that particular nuclear plant should be maintained. The use of an integrating dosimeter to measure the exposure resulting from the release of noble gases from a boiling water reactor would be an example of the kind of continuous monitoring required. In addition, a basic monitoring program such as that outlined in table 1 might be conducted on a periodic basis in order to keep the surveillance system operable.

Although the previous discussion has been concerned with environmental surveillance requirements, it should be noted that the discharge of radioactive materials from nuclear facilities is

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regulated by the Atomic Energy Commission so that the levels leaving the controlled area will not exceed concentrations established in Title 10, Part 20 of the Code of Federal Regulations (10CFR20) (*12*). In the case of the liquid effluent, average concentrations in the condenser water cooling canal at the point of discharge must stay within these limits. For gaseous discharges, the discharge rate is controlled and limits established so that average concentrations in the atmosphere will not exceed 10CFR20 values at the site boundary.

Multiple reactor sources

The large increase in the number of nuclear power plants has resulted in the location of more than one reactor at some sites. In addition, some reactor sites are planned to be sufficiently close together so that many will share the same air, water, and terrestrial environment. This trend dictates that potential environmental problems be assessed on an area or regional basis. These factors must now be considered in establishing both Bureau and State health agency environmental surveillance activities so that the radioactivity that might result from nuclear power sources can be evaluated over relatively large geographic areas. Such evaluations must consider the possible long-term buildup of radioactivity in the aquatic environment, including reconcentration phenomena in biological media that might result in population exposure. Multiple reactor sites also present regulatory problems relative to the establishment of radioactive effluent discharge limits. These limits will have to be developed carefully, using the best available information on the many environmental aspects that influence the possible population exposure to assure that the total dose to the population from multiple reactor sources is within acceptable limits based on Federal Radiation Council guidance.

Summary

An analysis of data from nuclear plants currently operating in the United States has shown that discharges of radioactive wastes have generally been small percentages of AEC regulatory limits and have resulted in minimal or undetectable radiation exposure to the population. Studies carried out to date by the Bureau of Radiological Health have confirmed this to be the case. If good waste management practices are carefully followed by reactor plant operators, the resulting radiation exposures to the public should continue to be extremely low. However, the existence of multiple reactor sites and areas containing several sites will require that monitoring programs be designed to consider the possibility of radiation effects from a large number of nuclear power sources.

Because of the large number of nuclear plants which will ultimately require surveillance programs, efforts are being made by the Bureau to reevaluate recommendations for environmental surveillance programs for maximum effectiveness. Results of field studies conducted thus far indicate that a surveillance program as previously described will satisfy public health requirements if the effluents are well defined and if the critical radionuclides in the effluents and pathways to the population are clearly identified.

The Bureau of Radiological Health will continue to carry out its responsibility for evaluating the environmental levels of radioactivity through a nationwide surveillance program, technical assistance to States, research and development activities, and the analysis of environmental radiation data from all sources. This function is currently being strengthened to insure an adequate evaluation of the impact of the growing nuclear power industry on radiation levels in the environment and the continued protection of the public health.

REFERENCES

(*1*) BLOMEKE, J. O. and F. E. HARRINGTON. Management of Radioactive Wastes at Nuclear Power Stations, AEC Report ORNL-4070. Oak Ridge National Laboratory, Oak Ridge, Tenn. (1968).

(*2*) LOGSDON, J. E. and R. I. CHISSLER. Radioactive Waste Discharges to the Environment from Nuclear Power Facilities, BRH/DER 70-2. Division of Environmental Radiation, Bureau of Radiological Health, PHS (March 1970).

(*3*) JOINT COMMITTEE ON ATOMIC ENERGY. Environmental Effects of Producing Electric Power, Hearings before the Joint Committee on Atomic Energy, Part I (1969).

10

(4) TERRILL, J. G., JR., C. L. WEAVER, E. D. HARWARD, and D. R. SMITH. Environmental surveillance of nuclear facilities. Nucl Safety 9:143-149 (March-April 1968).

(5) WEAVER, C. L. and E. D. HARWARD. Surveillance of nuclear power reactors. Public Health Rep 82:899-912 (October 1967).

(6) DIVISION OF ENVIRONMENTAL RADIATION, BRH. Radiological Surveillance Studies at a Boiling Water Nuclear Power Reactor, BRH/DER 70-1. Radiological Engineering Laboratory, Division of Environmental Radiation, Bureau of Radiological Health, Cincinnati, Ohio. 45213 (March 1970).

(7) RADIOLOGICAL ENGINEERING LABORATORY, BRH. Radiological Surveillance Studies at a Pressurized Water Nuclear Power Reactor, BRH/DER 70-3. Radiological Engineering Laboratory, Division of Environmental Radiation, Bureau of Radiological Health, Cincinnati, Ohio 45213 (To be published fall 1970).

(8) PETERSON, H. T., J. E. MARTIN, C. L. WEAVER, and E. D. HARWARD. Environmental Tritium Contamination from Increasing Utilization of Nuclear Energy Sources. Proceedings of IAEA-FAO Seminar on Agricultural and Public Health Aspects of Environmental Contamination by Radioactive Materials, Vienna (March 24-28, 1969).

(9) WEAVER, C. L., E. D. HARWARD, and H. T. PETERSON. Tritium in the environment from nuclear power plants. Public Health Rep 84:363-371 (April 1969).

(10) RAY, J. W. Tritium in power reactors. Reactor Fuel-Proc Techn 12:19-26 (Winter 1968-1969).

(11) BUREAU OF RADIOLOGICAL HEALTH. Tritium in surface water, January-June 1969. Radiol Health Data Rep 10:513-514 (November 1969).

(12) U.S. ATOMIC ENERGY COMMISSION. Code of Federal Regulations, Title 10, Part 20, Standards for Protection Against Radiation. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

SECTION I. MILK AND FOOD

Milk Surveillance, March 1970

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation and/or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Bureau of Radiological Health and the Bureau of Foods, Pesticides and Product Safety, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Public Health Service)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that occur in, or are formed as a result of, nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variation, expressed in terms of 2-standard deviations, for these con-

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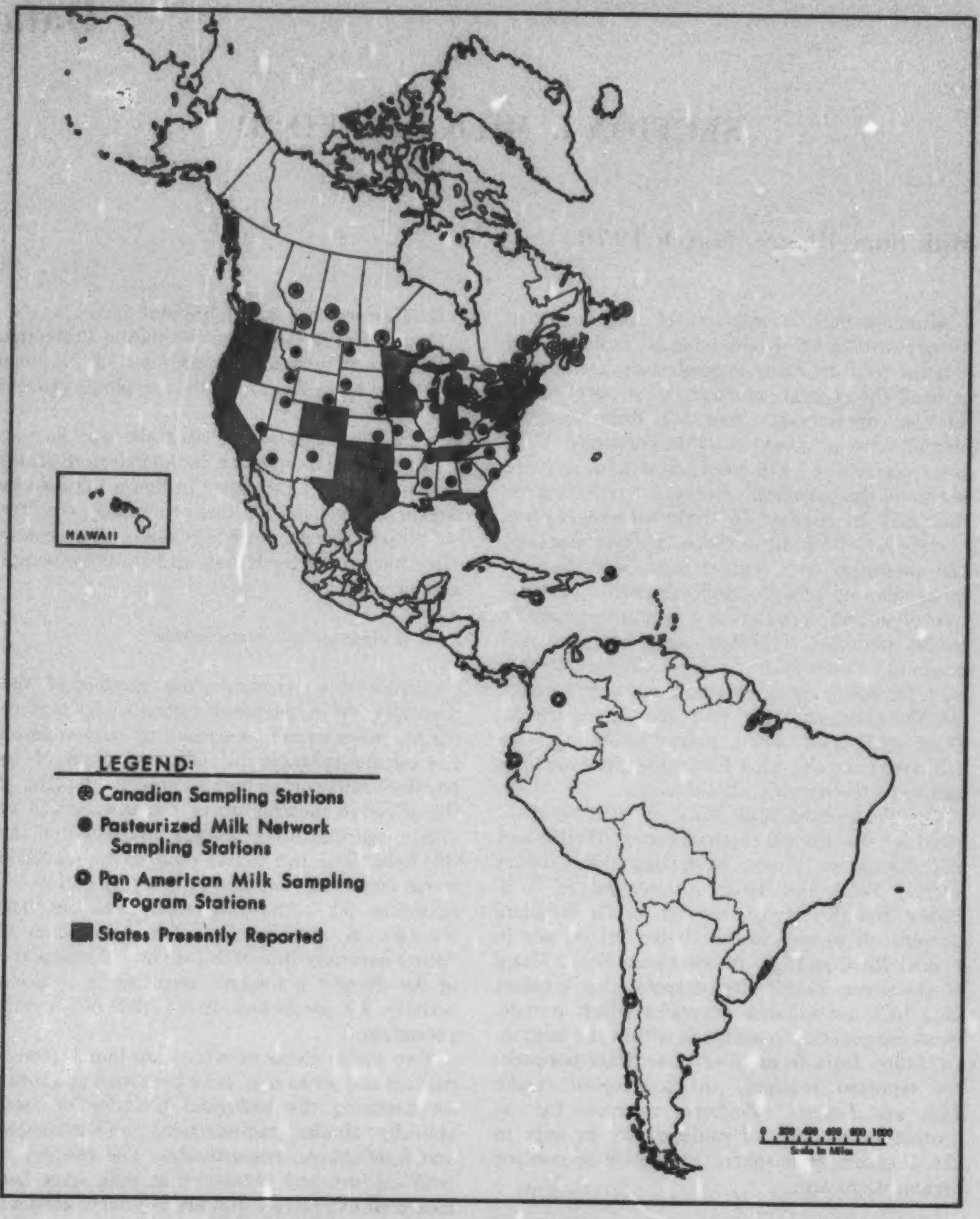
HAWAII
LEGEND:
⊕ Canadian Sampling Stations
● Pasteurized Milk Network Sampling Stations
○ Pan American Milk Sampling Program Stations
▨ States Presently Reported
0 200 400 600 800 1000
Scale in Miles

Figure 1. Milk sampling networks in the Western Hemisphere

centrations are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for the period, May 1963–March 1966 (*3*) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Bureau of Radiological Health conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested public health radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted in the period, July–September 1969, with 31 laboratories participating in an experiment on milk samples containing known concentrations of strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. Of the 18 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 14 participated in the experiment.

The iodine-131 and cesium-137 results show much improvement over previous tests. Barium-140 results also look good which is encouraging, since this is the first time barium-140 was analyzed for this type of experiment. However, strontium-89 and strontium-90 analyses still need improvement (*5*). Keeping these possible differences in mind, integration of the data from the various networks can be undertaken without introducing a serious error due to disagreement among the independently obtained data.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methodologies, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports.*

A recent article (*6*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and earlier data articles for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short time periods, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data presentation also reflects whether raw or pasteurized milk was collected. A recent analysis (*7*) of raw and pasteurized milk samples collected during January 1964 to June 1966, indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant. Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by

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the participating networks, most often based on 2-standard deviation counting errors or 2-standard deviation total analytical errors from replicate analyses experiments (3). The practical reporting level reflects additional analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurement equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical errors or precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (3). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium-89	1-5 pCi/liter for levels <50 pCi/liter; 5-10% for levels ≥50 pCi/liter;
Strontium-90	1-2 pCi/liter for levels <20 pCi/liter; 4-10% for levels ≥20 pCi/liter;
Iodine-131 Cesium-137 Barium-140	4-10 pCi/liter for levels <100 pCi/liter; 4-10% for levels ≥100 pCi/liter.

For iodine-131, cesium-137, and barium-140 there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions is presented below. The function of the Council is to provide guidance to Federal agencies in the formulation of radiation standards.

Radiation Protection Guides (8,9)

The Radiation Protection Guide (RPG) has been defined by the Federal Radiation Council (FRC) as the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable. An RPG provides radiation protection guidance for the control and regulation of normal peacetime uses of nuclear technology in which control is exercised primarily at the source through the design and use of nuclear material. It represents a balance between the possible risk to the general public that might result due to exposures from routine uses of ionizing radiation and the benefits from the activities causing the exposure.

Table 1 presents a summary of guidelines and related information on environmental radiation levels as set forth by the FRC for the conditions under which RPG's are applicable. A more detailed discussion of these values was presented earlier (3).

In the absence of specific dietary data one can use milk as the indicator food item for routine surveillance. Assuming a 1-liter per day intake of milk, one can utilize the graded approach of daily intake on the basis of radionuclide content in milk samples collected to represent general population consumption. Under these assumptions, the radionuclide concentrations in pCi/liter of milk can replace the daily radionuclide intake in pCi/day in the three graded ranges.

Table 1. Radiation Protection Guides—FRC recommendations and related information pertaining to environmental levels during normal peacetime operation

Radionuclide	Critical organ	RPG for individual in the general population (rad/a)	Guidance for suitable samples of exposed population group[a]				
			RPG (rad/a)	Corresponding continuous daily intake (pCi/day)	Range I[b] (pCi/day)	Range II[b] (pCi/day)	Range III[b] (pCi/day)
Strontium-89	Bone	[c]1.5	0.5	[d]2,000	0-200	200-2,000	2,000-20,000
	Bone marrow	[c] .5	.17				
Strontium-90	Bone	[c]1.5	.5	[d]200	0-20	20-200	200-2,000
	Bone marrow	[c] .5	.17				
Iodine-131	Thyroid	1.5	.5	100	0-10	10-100	100-1,000
Cesium-137[e]	Whole body	.5	.17	3,600	0-360	360-3,600	3,600-36,000

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[a] Suitable samples which represent the limiting conditions for this guidance are: strontium-89, strontium-90—general population; iodine-131—children 1 year of age; cesium-137—infants.

[b] Based on an average intake of 1 liter of milk per day.

[c] A dose of 1.5 rad/a to the bone is estimated to result in a dose of 0.5 rad/a to the bone marrow.

[d] For strontium-89 and strontium-90, the Council's study indicated that there is currently no operational requirement for an intake value as high as one corresponding to the RPG. Therefore, these intake values correspond to doses to the critical organ not greater than one-third the respective RPG.

[e] The guides expressed here were not given in the FRC reports, but were calculated using appropriate FRC recommendations.

Protective Action Guides (*10,11*)

The Protective Action Guide (PAG) has been defined by the Council as the projected absorbed dose to individuals in the general population that warrants protective action following a contaminating event. A PAG provides general guidance for the protection of the population against exposure by ingestion of contaminated foods resulting from the accidental release or the unforeseen dispersal of radioactive materials in the environment. A PAG is also based on the assumption that such an occurrence is an unlikely event, and circumstances that might involve the probability of repetitive occurrences during a 1- or 2-year period in a particular area would require special consideration. Protective actions are appropriate when the health benefits associated with the reduction in exposure to be achieved are sufficient to offset the undesirable features of the protective actions.

Table 2 presents a summary of guidelines as set forth by the FRC for the conditions under which PAG's are applicable. A more detailed discussion of these values was presented earlier (*3*). Also given in table 2 are milk concentrations for each of the radionuclides considered, in the absence of others, which if attained after an acute incident, would result in doses equivalent to the appropriate PAG. These concentrations are based on a projection of the maximum concentration from an idealized model for any acute deposition and the pasture-cow-milk-man pathway, as well

Table 2. Protective Action Guides—FRC recommendations and related information pertaining to environmental levels during an acute contaminating event

Radionuclide	Critical organ	PAG for individuals in general population (rads)	Category (pasture-cow-milk)	
			Guidance for suitable sample, children 1 year of age	
			PAG (rads)	Maximum concentration in milk for single nuclide that would result in PAG (pCi/liter)
Strontium-89	Bone marrow	10 in first yr; total dose not to exceed 15[a,b]	3 in first yr; total dose not to exceed 5[a,b]	[c]1,110,000
Strontium-90	Bone marrow			[c]51,000
Cesium-137	Whole body			[c]720,000
Iodine-131	Thyroid	30	10	[d]70,000

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[a] The sum of the projected doses of these three radionuclides to the bone marrow should be compared to the numerical value of the respective guide.

[b] Total dose from strontium-89 and cesium-137 is the same as dose in first year; total dose from strontium-90 is 5 times strontium-90 dose in first year for children approximately 1 year of age.

[c] These values represent concentrations that would result in doses to the bone marrow or whole body equal to the PAG, if only the single radionuclide were present.

[d] This concentration would result in the PAG dose based on intake before and after the date of maximum concentration observed in milk from an acute contaminating event. A maximum of 84,000 pCi/liter would result in a PAG dose if that portion of intake prior to the maximum concentration in milk is not considered. Children, 1 year of age, are assumed to be the critical segment of the population.

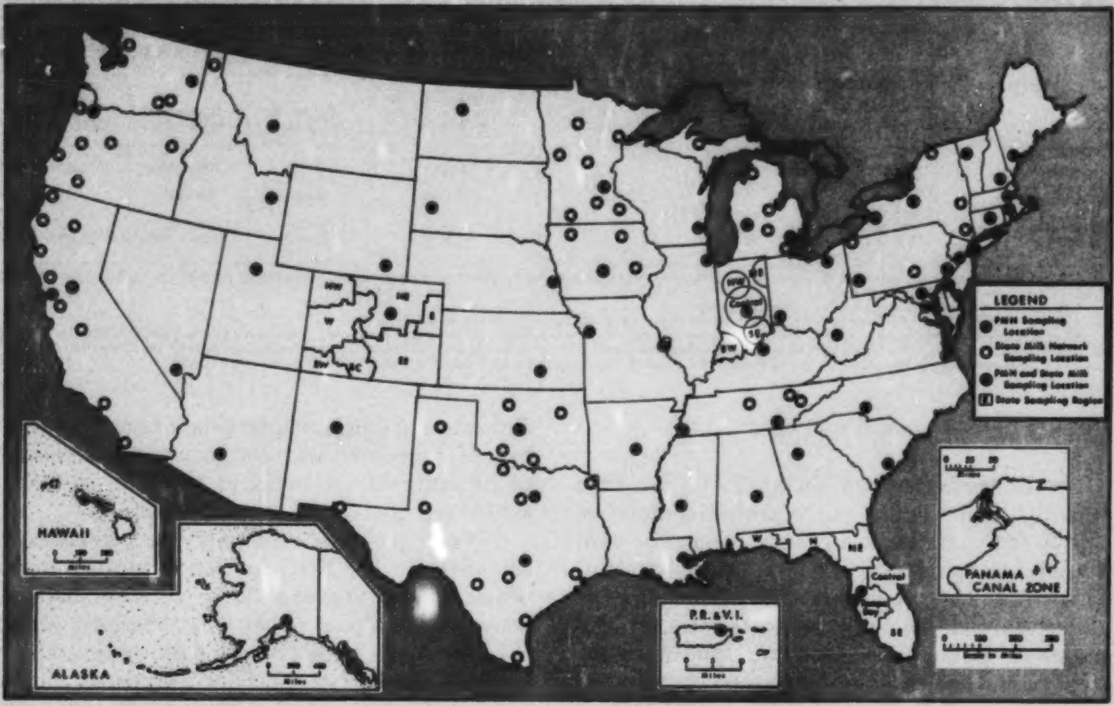

Figure 2. State and PMN milk sampling locations in the United States

as an estimate of the intake prior to reaching the maximum concentration. Therefore, these maximum concentrations are intended for use in estimating future intake on the basis of a few early samples rather than in retrospective manner.

Data reporting format

Table 3 presents the integrated results of the international, national and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports*. (The relationship between the PMN stations and State stations is shown in figure 2). The first column under each of the radionuclides reported gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12-monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 3, surveillance results are given for strontium-90, iodine-131 and cesium-137 for March 1970 and the 12-month period, April 1969 to March 1970. Except where noted the monthly average represents a single sample for the sampling

Table 3. Concentration of radionuclides in milk for March 1970 and 12-month period, April 1969 through March 1970

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES:								
Ala:	Montgomery[c]	P	8	7	0 (4)	0	7 (4)	9
Alaska:	Palmer[c]	P	5	6	0 (5)	0	3 (5)	5
Ariz:	Phoenix[c]	P	0	1	0 (4)	0	0 (4)	0
Ark:	Little Rock[c]	P	12	15	0 (5)	0	17 (5)	18
Calif:	Sacramento[c]	P	3	2	0 (4)	0	0 (4)	0
	San Francisco[c]	P	4	2	0 (4)	0	0 (4)	0
	Del Norte	P	23	19	0	0	24	19
	Fresno	P	2	3	0	0	0	5
	Humboldt	P	5	4	0	0	0	6
	Los Angeles	P	2	2	0	0	0	2
	Mendocino	P	4	3	0	0	0	4
	Sacramento	P	3	3	0	0	0	4
	San Diego	P	0	2	0	0	0	2
	Santa Clara	P	2	2	0	0	0	4
	Shasta	P	2	3	0	0	0	4
	Sonoma	P	3	2	0	0	0	4
Colo:	Denver[c]	P	6	5	0 (4)	0	0 (4)	1
	West	R	(d)		(e)	(e)	25	(e)
	Northeast	R	(d)		(e) (2)	(e)	(e) (2)	(e)
	East	R	(d)		(e)	(e)	(e)	(e)
	Southeast	R	(d)		(e)	(e)	(e)	(e)
	South central	R	(d)		NS	(e)	NS	(e)
	Southwest	R	(d)		(e)	(e)	35	(e)
	Northwest	R	(d)		NS	(e)	NS	(e)
Conn:	Hartford[c]	P	7	8	0 (4)	0	11 (4)	11
	Central	P	NS		NS		NS	
Del:	Wilmington[c]	P	10	8	0 (4)	0	6 (4)	5
D.C:	Washington[c]	P	8	7	0 (4)	0	5 (4)	5
Fla:	Tampa[c]	P	5	6	0 (4)	0	44 (4)	54
	West	R	8	11	0	0	0	22
	North	R	6	13	0	0	14	25
	Northeast	R	7	7	0	0	55	53
	Central	R	6	7	0	0	17	43
	Tampa Bay area	R	6	6	0	0	44	55
	Southeast	R	7	7	0	0	40	80
Ga:	Atlanta[c]	P	8	9	0 (4)	0	11 (4)	18
Hawaii:	Honolulu[c]	P	2	2	0 (5)	0	3 (5)	0
Idaho:	Idaho Falls[c]	P	3	5	0 (5)	0	0 (5)	3
Ill:	Chicago[c]	P	6	7	0 (5)	0	5 (5)	9
Ind:	Indianapolis[c]	P	8	8	0 (5)	0	2 (5)	4
	Northeast	P	8	10	0	1	10	11
	Southeast	P	12	9	0	0	15	11
	Central	P	10	9	0	0	0	10
	Southwest	P	9	10	0	0	10	13
	Northwest	P	10	10	0	0	10	17
Iowa:	Des Moines[c]	P	8	6	0 (4)	0	0 (4)	2
	Iowa City	P	NS		NS		NS	
	Des Moines	P	NS		NS		NS	
	Spencer	P	NS		NS		NS	
	Fredericksburg	P	NS		NS		NS	
Kans:	Wichita[c]	P	8	8	0 (5)	0	0 (5)	1
Ky:	Louisville[c]	P	8	8	0 (4)	0	3 (4)	4
La:	New Orleans[c]	P	13	16	0 (4)	0	20 (4)	18
Maine:	Portland[c]	P	9	11	0 (4)	0	17 (4)	23
Md:	Baltimore[c]	P	6	8	0 (5)	0	3 (5)	6
Mass:	Boston[c]	P	8	11	0 (5)	0	11 (5)	20
Mich:	Detroit[c]	P	8	8	0 (5)	0	9 (5)	8
	Grand Rapids[c]	P	6	9	0 (5)	0	10 (5)	11
	Bay City	P	6	7	(e) (3)	(e)	4 (3)	9
	Charlevoix	P	13	11	(e) (3)	(e)	17 (3)	18
	Detroit	P	6	6	(e) (5)	(e)	5 (5)	6
	Grand Rapids	P	9	8	(e) (5)	(e)	15 (5)	12
	Lansing	P	8	7	(e) (3)	(e)	15 (3)	14
	Marquette	P	14	11	(e) (2)	(e)	23 (2)	25
	Monroe	P	5	6	(e) (2)	(e)	11 (2)	2
	South Haven	P	NA	7	(e) (1)	(e)	13 (1)	11
Minn:	Minneapolis[c]	P	9	10	0 (5)	0	4 (5)	7
	Bemidji	P	13	17	0	0	20	24
	Mankato	P	6	8	0	0	12	0
	Rochester	P	7	8	0	0	0	0
	Duluth	P	12	18	0	0	25	22
	Worthington	P	5	7	0	0	0	0
	Minneapolis	P	8	13	0	0	14	0
	Fergus Falls	P	5	9	0	0	14	0
	Little Falls	P	10	9	0	0	20	0
Miss:	Jackson[c]	P	9	12	0 (5)	0	7 (5)	13
Mo:	Kansas City[c]	P	6	8	0 (4)	0	0 (4)	1
	St. Louis[c]	P	4	8	0 (4)	0	3 (4)	2
Mont:	Helena[c]	P	4	5	0 (4)	0	5 (4)	5
Nebr:	Omaha[c]	P	7	6	0 (3)	0	0 (3)	1
Nev:	Las Vegas[c]	P	2	0	0 (5)	0	0 (5)	0
N.H:	Manchester[c]	P	8	8	0 (5)	0	8 (5)	18

See footnotes at end of table.

Table 3. Concentration of radionuclides in milk for March 1970 and 12-month period, April 1969 through March 1970—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES—Continued								
N.J.:	Trenton[c]	P	7	9	0 (5)	0	4 (5)	6
N.Mex:	Albuquerque[c]	P	4	3	0 (5)	0	0 (5)	0
N.Y:	Buffalo[c]	P	6	7	0 (4)	0	12 (4)	8
	New York City[c]	P	10	10	0 (5)	0	13 (5)	12
	Syracuse[c]	P	8	7	0 (5)	0	9 (5)	9
	Albany	P	(e)	4	0 (6)	0	(e) (6)	(e)
	Buffalo	P	(e) (2)	(e)	0 (2)	0	(e) (2)	(e)
	Massena	P	(e) (3)	7	0 (2)	0	22 (2)	(e)
	Newburg	P	12	6	0 (1)	0	(e)	(e)
	New York City	P	(e) (5)	7	0 (5)	0	(e) (5)	(e)
	Syracuse	P	(e)	3	0	0	(e) (2)	(e)
N.C:	Charlotte[c]	P	11	12	0 (5)	0	14 (5)	13
N.Dak:	Minot[c]	P	12	10	0 (5)	0	16 (5)	14
Ohio:	Cincinnati[c]	P	6	8	0 (4)	0	7 (4)	2
	Cleveland[c]	P	9	9	0 (4)	0	6 (4)	5
Oklahoma:	Oklahoma City[c]	P	6	7	0 (5)	0	3 (5)	8
	Oklahoma City	P	NS		NS		NS	
	Enid	P	NS		NS		NS	
	Tulsa	P	NS		NS		NS	
	Lawton	P	NS		NS		NS	
	Ardmore	P	NS		NS		NS	
Ore:	Portland[c]	P	8	7	0 (4)	0	5 (4)	6
	Baker	P	4	3	(e)	(e)	0	0
	Coos Bay	P	4	6	(e)	(e)	0	0
	Eugene	P	2	3	(e)	(e)	0	0
	Medford	P	3	2	(e)	(e)	0	0
	Portland composite	P	7	4	(e)	(e)	0 (4)	6
	Portland local	P	4	5	(e)	(e)	0 (4)	9
	Redmond	P	6	2	(e)	(e)	0	3
	Tillamook	P	9	7	(e)	(e)	20	16
Pa:	Philadelphia[c]	P	8	9	0 (3)	0	8 (3)	4
	Pittsburgh[c]	P	10	11	0 (5)	0	11 (5)	8
	Dauphin	P	4	7	0	2	0	15
	Erie	P	10	10	13	7	21	24
	Philadelphia	P	7	8	0	5	11	13
	Pittsburgh	P	6	11	0	3	29	20
R.I:	Providence[c]	P	7	9	0 (4)	0	5 (4)	15
S.C:	Charleston[c]	P	9	10	0 (4)	0	18 (4)	23
S.Dak:	Rapid City[c]	P	6	8	0 (4)	0	0 (4)	4
Tenn:	Chattanooga[c]	P	9	10	0 (3)	0	4 (3)	12
	Memphis[c]	P	8	9	0 (4)	0	2 (4)	4
	Chattanooga	P	9	12	0 (5)	0	13 (5)	14
	Clinton	P	17	16	0 (2)	1	12 (2)	12
	Knoxville	P	7	7	0 (2)	0	17 (2)	5
	Nashville	P	7	8	0	0	16 (2)	6
	Fayetteville	P	7	7	0	0	21 (2)	21
Tex:	Austin[c]	P	4	2	0 (5)	0	3 (5)	4
	Dallas[c]	P	6	6	0 (4)	0	11 (4)	6
	Amarillo	R	2	4	0	0	0	0
	Corpus Christi	R	NS	5	NS	0	NS	2
	El Paso	R	NS	2	NS	0	NS	0
	Fort Worth	R	NS	6	NS	0	NS	5
	Harlingen	R	4	3	0	0	0	0
	Houston	R	NS	8	NS	0	NS	15
	Lubbock	R	NS	4	NS	0	NS	0
	Midland	R	NS	2	NS	0	NS	0
	San Antonio	R	4	4	0	0	0	0
	Texarkana	R	NS	11	NS	0	NS	12
	Uvalde	R	NS	2	NS	0	NS	0
	Wichita Falls	R	NS	7	NS	0	NS	8
Utah:	Salt Lake City[c]	P	3	4	0 (5)	0	0 (5)	3
Vt:	Burlington[c]	P	8	8	0 (4)	0	9 (4)	12
Va:	Norfolk[c]	P	9	10	0 (4)	0	6 (4)	8
Wash:	Seattle[c]	P	7	7	0 (4)	0	0 (4)	9
	Spokane[c]	P	5	6	0 (5)	0	2 (5)	3
	Benton County	R	0	1	0	0	0	7
	Franklin County	R	NS	2	NS	0	NS	2
	Sandpoint, Idaho	R	7	11	0	0	18	26
	Skagit County	R	4	7	0	0	14	13
W.Va:	Charleston[c]	P	10	9	0 (4)	0	4 (4)	5
Wisc:	Milwaukee[c]	P	6	7	0 (4)	0	12 (4)	10
Wyo:	Laramie[c]	P	6	5	0 (4)	0	0 (4)	2
CANADA:								
Alberta:	Calgary	P	8	8	(d)		27	17
	Edmonton	P	6	7	(d)		24	16
British Columbia:	Vancouver	P	11	10	(d)		21	31
Manitoba:	Winnipeg	P	8	8	(d)		21	24
New Brunswick:	Fredericton	P	10	13	(d)		26	10
Newfoundland:	St. Johns	P	11	17	(d)		32	34

See footnotes at end of table.

Table 3. Concentration of radionuclides in milk for March 1970 and 12-month period, April 1969 through March 1970—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA—Continued								
Nova Scotia:	Halifax	P	9	10	(d)		15	20
Ontario:	Ft. William	P	14	15	(d)		20	20
	Ottawa	P	5	8	(d)		10	13
Ontario:	Sault Ste. Marie	P	14	14	(d)		20	20
	Toronto	P	5	5	(d)		20	10
	Windsor	P	4	5	(d)		9	9
Quebec:	Montreal	P	7	8	(d)		10	17
	Quebec	P	9	11	(d)		20	20
Saskatchewan:	Regina	P	8	7	(d)		10	12
	Saskatoon	P	9	7	(d)		8	10
CENTRAL AND SOUTH AMERICA:								
Columbia:	Bogota	P	2	2	0	0	0	3
Chile:	Santiago	P	0	0	0	0	0	2
Ecuador:	Guayaquil	P	0	0	0	0	0	0
Jamaica:	Montego Bay	P	6	5	0	0	150	95
Venezuela:	Caracas	P	2	2	0	0	0	0
Canal Zone:	Cristobal[c]	P	0	0	0 (5)	0	9 (5)	9
Puerto Rico:	San Juan[c]	P	3	3	0 (4)	0	5 (4)	8
PMN network average[f]			7	7	0	0	6	8

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[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] PHS Pasteurized Milk Network station. All other sampling locations are part of the State or national network.

[d] Radionuclide analysis not routinely performed.

[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:

Iodine-131: Colorado—25 pCi/liter
Michigan—14 pCi/liter
Oregon—15 pCi/liter

Cesium-137: Colorado—25 pCi/liter
New York—20 pCi/liter
Oregon—15 pCi/liter

Strontium-90: New York—3pCi/liter

[f] This entry gives the average radionuclide concentrations for the PHS Pasteurized Milk Network stations denoted by footnote [c].
NA, no analysis.
NS, no sample.

station. Strontium-89 and barium-140 data have been omitted from table 3 since levels at the great majority of the stations for March 1970 were below the respective practical reporting levels. The following station averages reflect samples in which strontium-89 was detected: Calif., Del Norte (State) 27 pCi/liter and Humboldt (State) 6 pCi/liter.

Iodine-131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower values reflected by the radiation protection guidance provided by the Federal Radiation Council (table 1), levels in milk for this radionuclide are of particular public health interest. In general, the practical reporting level for iodine-131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Strontium-90 monthly averages ranged from 0 to 23 pCi/liter in the United States for the month of March 1970 and the highest 12-month average was 19 pCi/liter (Del Norte, Calif.), representing 9.5 percent of the Federal Radiation Council radiation protection guide (table 1). Cesium-137 monthly averages ranged from 0 to 55 pCi/liter in the United States for the month of March 1970 and the highest 12-month average was 80 pCi/liter (Southeast Fla.), representing 2.2 percent of the value presented in this report using the recommendations given in the Federal Radiation Council reports. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (*12*) and Jamaica. Iodine-131 results for individual samples were all below the practical reporting level with the exception of Erie, Pa. (State) 13 pCi/liter.

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Acknowledgement

Appreciation is expressed to the personnel of the following health agencies who provide data for their milk surveillance networks:

Bureau of Radiological Health
Division of Environmental Sanitation
California State Department of Health

Radiological Health Section
Division of Air, Occupational and
Radiation Hygiene
Colorado State Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiological Health Service
Division of Occupational Health
Michigan Department of Health

Radiation Protection Division
Canadian Department of National
Health and Welfare

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Health
Division of Environmental Health Services
New York State Department of Health

Division of Occupational and Radiological
Health
Environmental Health Services
Oklahoma State Department of Health

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Office of Air Quality Control
Division of Technical Services
Washington State Department of Health

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REFERENCES

(*1*) CAMPBELL, J. E., G. K. MURTHY, A. S. GOLDIN, H. B. ROBINSON, C. P. STRAUB, F. J. WEBER and K. H. LEWIS. The occurrence of strontium-90, iodine-131, and other radionuclides in milk, May 1957 through April 1958. Amer J Public Health 49:225 (February 1959).

(*2*) Chart of the Nuclides, Ninth Edition revised to July 1966. Knolls Atomic Power Laboratory (November 1966).

(*3*) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Section I. Milk Surveillance. Radiol Health Data Rep 9:730–746 (December 1968).

(*4*) ROSENSTEIN, M. and A. S. GOLDIN. Statistical technics for quality control of environmental radioassay. Health Lab Sci 2:93 (April 1965).

(*5*) KNOWLES, F. Interlaboratory study of iodine-131, cesium-137, barium-140, strontium-89, and strontium-90 measurements in milk, July–September 1969. Technical experiment 69–MKAQ–2. Analytical Quality Control Service, Bureau of Radiological Health (October 1969).

(*6*) NEILL, R. H. and D. R. SNAVELY. State Health Department sampling criteria for surveillance of radioactivity in milk. Radiol Health Data Rep 8:621–627 (November 1967).

(*7*) ROBINSON, P. B. A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966. Radiol Health Data Rep 9:475–488 (September 1968).

(*8*) FEDERAL RADIATION COUNCIL. Background materials for the development of radiation protection standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 13, 1960).

(*9*) FEDERAL RADIATION COUNCIL. Background materials for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

(*10*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 5. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (July 1964).

(*11*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, protective action guides for strontium-89, strontium-90, and cesium-137, Report No. 7. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1965).

(*12*) PORTER, C. R., C. R. PHILLIPS, M. W. CARTER, and B. KAHN. The Cause of Relatively High Cesium-137 Concentrations in Tampa, Florida, Milk. Radioecological Concentration Processes, Proceedings of an International Symposium held in Stockholm, April 25–29, 1966. Pergamon Press, New York, N.Y. (1966) pp. 95–101.

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows:

Program	Period reported	Issue
Connecticut Diet Study	July–December 1968 and January–June 1969	February 1970
California Diet Study	October–December 1968 and January–March 1969	May 1970
Radionuclides in Institutional Diet Samples, *HASL*	July–September 1969	June 1970
Tri-City Diet Study,	January–December 1969	June 1970

SECTION II. WATER

The Public Health Service, the Federal Water Quality Administration and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2-4*), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

Water sampling program	Period reported	Issue
California	January–June 1968	December 1969
Coast Guard Water Supplies	January 1968–July 1969	February 1970
Florida	1968	March 1970
Minnesota	January–June 1969	January 1970
New York	July–December 1968	September 1969
North Carolina	January–December 1967	May 1969
Washington	July 1967–June 1968	June 1969

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[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unindentified alpha-particle emitters and strontium-90, respectively.

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Radiostrontium in Tap Water, January-December 1969[1]

Health and Safety Laboratory
U.S. Atomic Energy Commission

The Health and Safety Laboratory has performed analyses for strontium-90 in tap water at New York City since August 1954. Samples of tap water are collected daily so that by the end of the month a composite of at least 100 liters is is available for analysis. Cesium-137 determinations were begun in January 1964. The analytical methods used at the laboratory are given in the Health and Safety Laboratory Manual of Standard Procedures (*1*).

Strontium-90 concentration and cesium-137 to strontium-90 ratios in New York City tap water for January through December 1969 are presented in table 1. These results appear graphically in figure 1.

A decreasing trend has been observed in the strontium-90 concentration since the July 1963 peak. The maximum strontium-90 concentrations observed are below the acceptable limit as set forth in the interstate carrier drinking water standards (*2*).

Table 1. Radiostrontium in New York City tap water January-December 1969

Date	Strontium-90[a] (pCi/liter)	Cesium-137/ strontium-90
January	0.58	0.08
February	.68	.06
March	.56	.08
April	.54	NA
May	.69	.08
June	.66	.10
July	.74	.06
August	.74	.09
September	.84	.10
October	.76	.09
November	.78	.08
December	.90	.08

[a] Approximately 100 liters per sample.
NA, no analysis.

REFERENCES

(*1*) U.S. ATOMIC ENERGY COMMISSION. Manual of standard procedures 40:E-38-01-16. Health and Safety Laboratory, U.S. Atomic Energy Commission, 376 Hudson Street, New York, N.Y. 10014.

(*2*) FEDERAL REGISTER RULES AND REGULATIONS. Title 42-Public Health, Chapter 1, Public Health Service, Department of Health, Education and Welfare; Part 72, Interstate Quarantine, Subpart J, Drinking Water Standards 27:2154-2155. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 6, 1962).

Recent coverage in *Radiological Health Data and Reports.*

Period	Issue
January-June 1968	April 1969
July-December 1968	November 1969

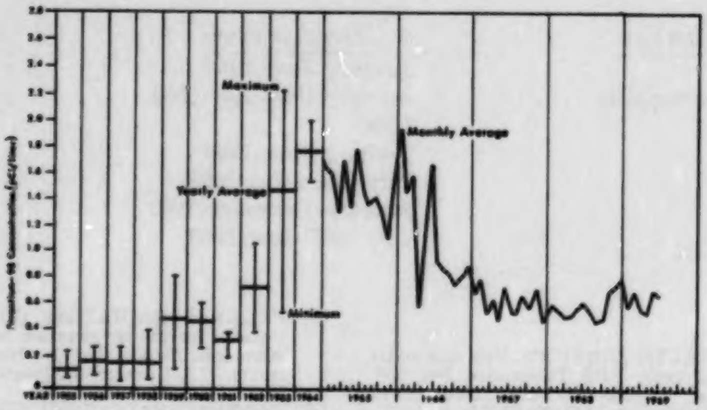

Figure 1. Strontium-90 concentrations in New York City tap water 1955-1969

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[1] Prepared from information appearing in Fallout Program Quarterly Summary Report, HASL 224. This report is available from the Clearinghouse for Federal Scientific and Technical Information, CESTI, 5285 Port Royal Road, Springfield, Va. 22151.

Tritium in Surface Water Network, July-December 1969

Bureau of Radiological Health
U.S. Public Health Services

The tritium sampling network was established by the Public Health Service in May 1964 to measure and monitor tritium concentrations in major river systems in the United States and to provide surveillance at selected surface water stations downstream from nuclear facilities. The network originally consisted of 10 stations selected from the 131 existing water pollution sampling stations operated by the Federal Water Quality Administration (FWQA); eight of the stations were located downstream from nuclear facilities and two stations served to establish baseline levels (figure 1). Two of these stations have been discontinued due to the difficulty of locating a new sampling point and the shutdown of a reactor.

Monthly composites of weekly samples are collected through the FWQA and sent to the Southeastern Radiological Health Laboratory for analysis. The analyses are carried out using liquid scintillation counting techniques described by Moghissi et al (*1*). The minimum level of detectability is 0.2 nCi/liter.

Data for the samples collected during the last 6 months of 1969 are shown in table 1. Station averages for this period and the corresponding period of 1968 are also presented in the table. The highest concentration observed during the last 6 months of 1969 was 5.3 nCi/liter (Clinch River—Kingston, Tenn.). The highest 6-month average, 2.7 nCi/liter, was also observed at the Clinch River station. Assuming that the specific activity of tritium in the body is essentially the same as that in the surface water, this average concentration corresponds to an estimated whole-

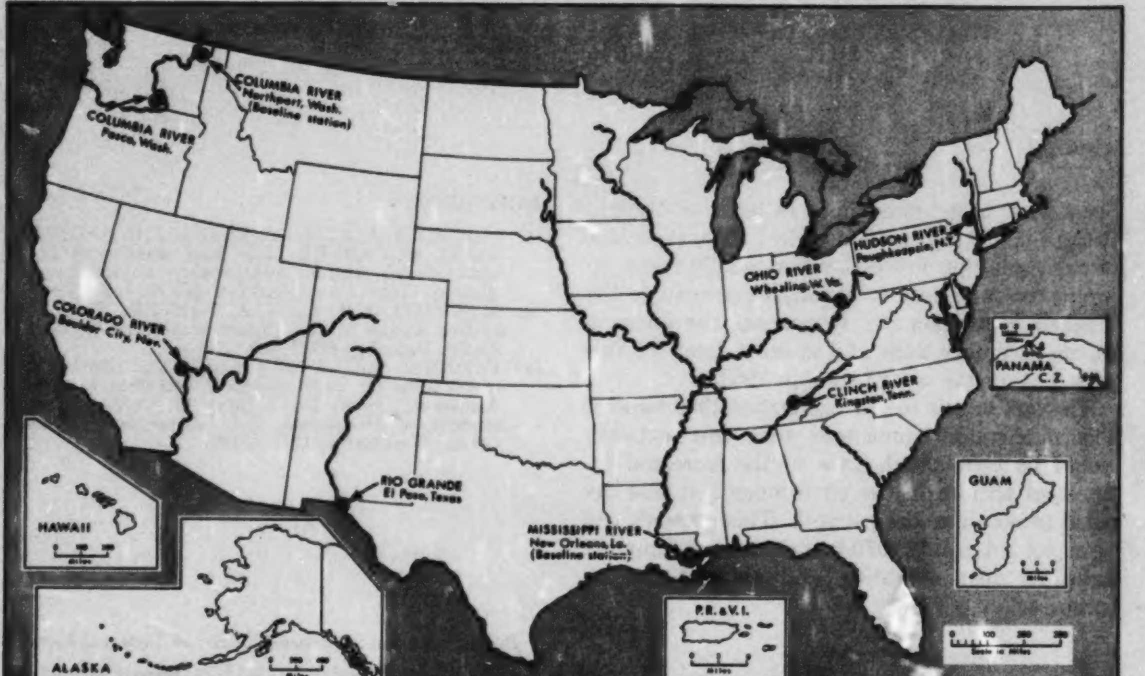
COLUMBIA RIVER
Northport, Wash.
(Baseline station)
COLUMBIA RIVER
Pasco, Wash.
COLORADO RIVER
Boulder City, Nev.
RIO GRANDE
El Paso, Texas
MISSISSIPPI RIVER
New Orleans, La.
(Baseline station)
OHIO RIVER
Wheeling, W. Va.
HUDSON RIVER
Poughkeepsie, N.Y.
CLINCH RIVER
Kingston, Tenn.
PANAMA
C. Z.
GUAM
HAWAII
ALASKA
P.R. & V.I.
0
100
200
300
Scale in Miles

Figure 1. Sampling stations for tritium in surface waters

Table 1. Tritium concentration in surface waters, July–December 1969

Collection site	Concentration[a] (nCi/liter)							
	1969						July–December average[b] for:	
	July	August	September	October	November	December	1968	1969
Clinch River: Kingston, Tenn.	1.7 ± 0.2	1.4 ± 0.3	1.3 ± 0.3	1.2 ± 0.1	5.0 ± 0.3	5.3 ± 0.3	1.7	2.7
Colorado River: Boulder City, Nev[c]	1.4 ± .2	NS	1.5 ± .2	1.4 ± .2	1.4 ± .2	1.2 ± 0.2	1.8	1.4
Columbia River: Northport, Wash.[c]	NS	.7 ± .2	.7 ± .2	NS	.8 ± .2	NS	.8	.7
Columbia River: Pasco, Wash.	.9 ± .2	.6 ± .2	.8 ± .2	.7 ± .2	1.0 ± .2	NS	.8	.8
Hudson River: Poughkeepsie, N.Y.	.2 ± .2	.4 ± .2	.4 ± .2	.6 ± .2	.4 ± .2	[d]<.2	.5	.3
Mississippi River: New Orleans, La.	.6 ± .2	<.2	<.2	NS	<.2	NS	.6	.2
Ohio River: Wheeling, W.Va.	.2 ± .2	.5 ± .2	.7 ± .2	NS	<.2	.4 ± .2	.2	.3
Rio Grande: El Paso, Tex.	.2 ± .2	0.3 ± .2	.2 ± .2	<.2	.2 ± .2	.2 ± .2	.2	.1

[a] The error reported is the 2-sigma error at the 95-percent confidence level.
[b] Values less than or equal to the minimum level of detectability (0.2 nCi/liter) were averaged as zero.
[c] Baseline station.
[d] Values are not statistically significant at the 95-percent confidence level.
NS, no sample.

body dose[1] of 0.4 mrem/a or in terms of Federal Radiation Council guidance, less than 1 percent of the Radiation Protection Guide (170 mrem/a) for an average dose to a suitable sample of the exposed population (*3*). In general, the 6-month station averages were at the same level for this period as for the same period in 1968.

The last article in the November 1969 issue of this publication announced that this network would be terminated. Due to the increased interest of tritium in the environment, it was decided to continue the network. This network will be expanded in July 1970 to include more sampling locations near operating and planned nuclear facilities.

REFERENCES

(*1*) MOGHISSI, A. A., H. L. KELLEY, J. E. REGNIER, and M. W. CARTER. Low-level counting by liquid scintillation-I. tritium measurement in homogeneous systems. Inter J Appl Rad Isotopes 20: 145 (1969).

(*2*) MOGHISSI, A. A. and C. R. PORTER. Tritium in surface waters in the United States, 1966. Radiol Health Data Rep 9:337–339 (1968).

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1 (May 13, 1960). Superintendent of Documents, U.S. Government Printing Office. Washington, D.C. 20402.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1968	November 1968
July–December 1968	June 1969
January–June 1969	November 1969

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[1] Development of the calculations to obtain this dose may be found in reference (*2*).

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SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports.*

Network	Period	Issue
Fallout in the United States and Other Areas, *HASL*	January–June 1968	October 1969
Plutonium in Airborne Particulates and Precipitation, *PHS*	July–September 1968	February 1970

1. Radiation Alert Network
March 1970

Bureau of Radiological Health
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 73 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate Bureau of Radiological Health officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Radiological Surveillance Branch, Division of Environmental Radiation, BRH, Rockville, Md. A detailed description of the sampling and analytical procedures was presented in the April 1968 issue of *Radiological Health Data and Reports*.

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during March 1970. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting station.

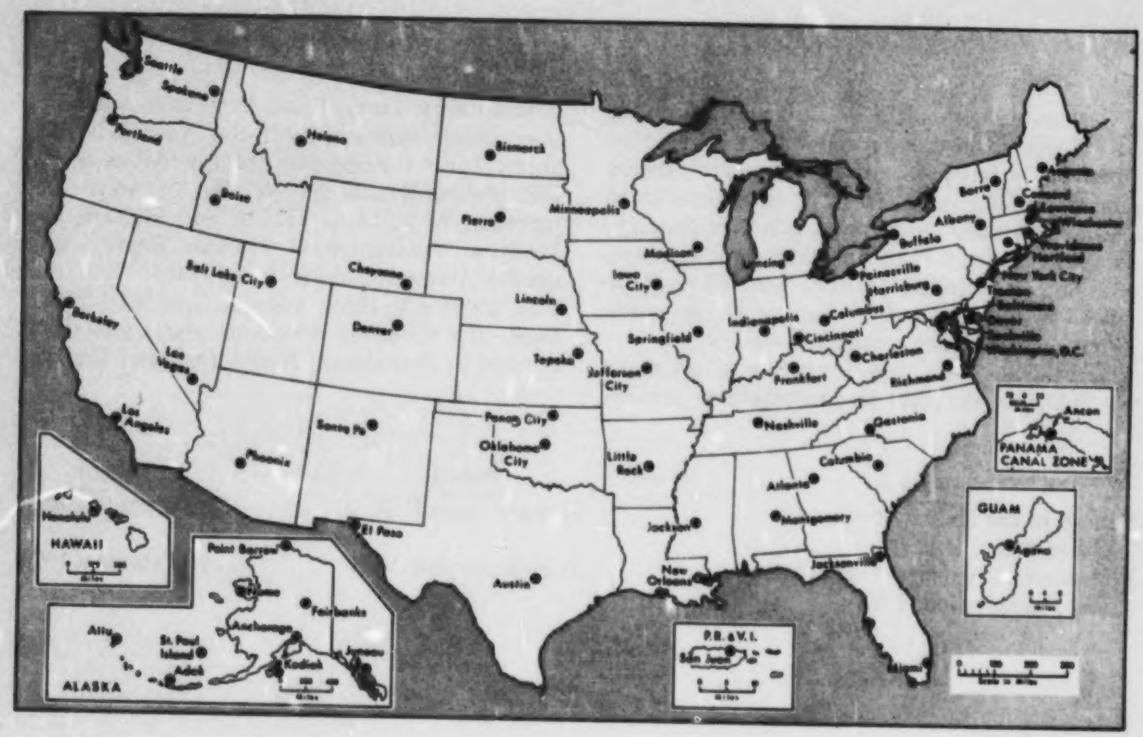
Seattle
Spokane
Portland
Helena
Bismarck
Boise
Pierre
Minneapolis
Salt Lake City
Cheyenne
Lincoln
Berkeley
Denver
Topeka
Las Vegas
Los Angeles
Santa Fe
Ponca City
Oklahoma City
Phoenix
El Paso
Austin
Honolulu
HAWAII
Miles
Point Barrow
Fairbanks
Anchorage
Attu
St. Paul Island
Adak
Kodiak
Juneau
ALASKA
Miles
Madison
Iowa City
Lansing
Springfield
Jefferson City
Indianapolis
Columbus
Cincinnati
Charleston
Frankfort
Richmond
Nashville
Gastonia
Little Rock
Columbia
Atlanta
Montgomery
Jackson
New Orleans
Jacksonville
Miami
Buffalo
Painesville
Harrisburg
Albany
Barre
Augusta
Concord
Lawrence
Winchester
Providence
Hartford
New York City
Trenton
Baltimore
Dover
Rockville
Washington, D.C.
Ancon
PANAMA CANAL ZONE
Miles
GUAM
Agana
Miles
P.R. & V.I.
San Juan
Miles
Scale in Miles

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, March 1970

Station location		Air surveillance: Number of samples	Gross beta radioactivity (pCi/m³): Maximum	Minimum	Average[a]	Last profile in RHD&R	Precipitation: Number of samples	Total depth (mm)	Field estimation of deposition: Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	21	4	0	1	Dec 69	3	51	3	51	11
Alaska:	Adak	(b)				Dec 69	(c)				
	Anchorage	8	0	0	0	June 70	(c)				
	Attu Island	18	0	0	0	Jan 70	(c)				
	Fairbanks	22	0	0	0	July 70	2	5	2	5	3
	Juneau	(b)				Oct 69	(c)				
	Kodiak	(b)				Nov 69	(c)				
	Nome	8	1	0	1	Mar 70	(c)				
	Point Barrow	(b)				Feb 70	(c)				
	St. Paul Island	(b)				Apr 70	(c)				
Ariz:	Phoenix	18	8	1	3	Oct 69	(c)				
Ark:	Little Rock	(b)				June 70	(c)				
Calif:	Berkeley	22	1	0	0	Nov 69	4	40	4	40	0
	Los Angeles	22	3	0	1	Mar 70	(c)				
C.Z:	Ancon	16	0	0	0	Nov 69	(c)				
Colo:	Denver	22	9	0	4	Nov 69	5	17	(d)		
Conn:	Hartford	19	1	0	0	July 70	7	50	7	50	11
Del:	Dover	21	1	0	0	May 70	(c)				
D.C:	Washington	24	2	0	0	Feb 70	(c)				
Fla:	Jacksonville	22	1	0	1	June 70	7	154	7	154	17
	Miami	14	9	0	0	July 70	4	82	4	82	0
Ga:	Atlanta	22	3	1	1	Apr 70	1	180	1	180	6
Guam:	Agana	(b)				May 70	(c)				
Hawaii:	Honolulu	25	2	0	1	Jan 70	1	7	(d)		
Idaho:	Boise	22	2	0	1	Jan 70	7	38	7	36	3
Ill:	Springfield	19	5	0	1	Feb 70	(c)				
Ind:	Indianapolis	(b)				Apr 70	(c)				
Iowa:	Iowa City	19	1	0	1	Nov 69	6	112	6	112	0
Kans:	Topeka	22	4	1	2	June 70	5	19	5	19	1
Ky:	Frankfort	8	1	0	1	Feb 70	(c)				
La:	New Orleans	12	0	0	0	Feb 70	8	196	(d)		
Maine:	Augusta	22	1	0	0	Mar 70	7	96	7	96	0
Md:	Baltimore	20	1	0	0	July 70	8	69	8	69	24
	Rockville	11	2	0	0	Jan 70	(c)				
Mass:	Lawrence	20	1	0	0	May 70	5	94	5	94	2
	Winchester	21	1	0	0	Dec 69	7	97	7	97	0
Mich:	Lansing	20	1	0	0	Jan 70	(c)				
Minn:	Minneapolis	21	0	0	0	May 70	4	58	4	58	9
Miss:	Jackson	14	1	0	0	Mar 70	4	144	4	144	49
Mo:	Jefferson City	22	2	0	1	Apr 70	7	41	7	41	0
Mont:	Helena	18	1	0	1	Dec 69	3	25	3	25	12
Nebr:	Lincoln	16	5	0	2	Apr 70	4	30	4	30	7
Nev:	Las Vegas	13	2	0	1	July 70	(c)				
N.H:	Concord	(b)				Feb 70	(c)				
N.J:	Trenton	20	1	0	0	Mar 70	7	104	7	104	7
N.Mex:	Santa Fe	15	3	0	1	Dec 69	4	16	4	16	1
N.Y:	Albany	(b)				Apr 70	(c)				
	Buffalo	21	1	0	0	Nov 69	(c)				
	New York City	8	1	0	0	Dec 69	(c)				
N.C:	Gastonia	15	11	1	3	Nov 69	4	72	(d)		
N.Dak:	Bismarck	21	1	0	0	Feb 70	5	26	5	26	1
Ohio:	Cincinnati	(b)				May 70	(c)				
	Columbus	5	1	0	1	Mar 70	(c)				
	Painesville	19	1	0	1	July 70	8	53	8	53	13
Okla:	Oklahoma City	(b)				Jan 70	(c)				
	Ponca City	21	11	0	2	July 70	6	37	6	37	0
Ore:	Portland	22	1	0	0	Apr 70	9	76	9	76	5
Pa:	Harrisburg	17	1	0	0	Apr 70	1	23	1	23	6
P.R:	San Juan	6	5	1	3	Mar 70	(c)				
R.I:	Providence	19	2	0	1	Jan 70	2	56	2	56	7
S.C:	Columbia	19	4	0	1	Dec 69	3	157	3	157	29
S.Dak:	Pierre	13	2	1	1	Oct 69	(c)				
Tenn:	Nashville	21	2	0	1	Jan 70	9	92	9	92	14
Tex:	Austin	13	4	0	2	May 70	(c)				
	El Paso	(b)				Feb 70	(c)				
Utah	Salt Lake City	31	4	0	1	Mar 70	8	30	8	30	1
Vt:	Barre	13	1	0	0	June 70	4	33	4	33	2
Va:	Richmond	22	1	0	0	June 70	7	91	7	91	12
Wash:	Seattle	25	0	0	0	June 70	7	54	(d)		
	Spokane	19	1	0	1	May 70	(c)				
W.Va:	Charleston	16	2	0	1	Dec 69	9	60	9	60	7
Wis:	Madison	22	1	0	0	June 70	4	27	4	27	7
Wyo:	Cheyenne	22	4	0	2	July 70	5	330	5	330	27
Network summary		1,080	11	0	1		5	73	5	74	8

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] No report received. (Air samples received without field estimate data are not considered by the data program.)
[c] No precipitation sample collected.
[d] This station is part of the plutonium in precipitation network. No gross beta measurements are done.

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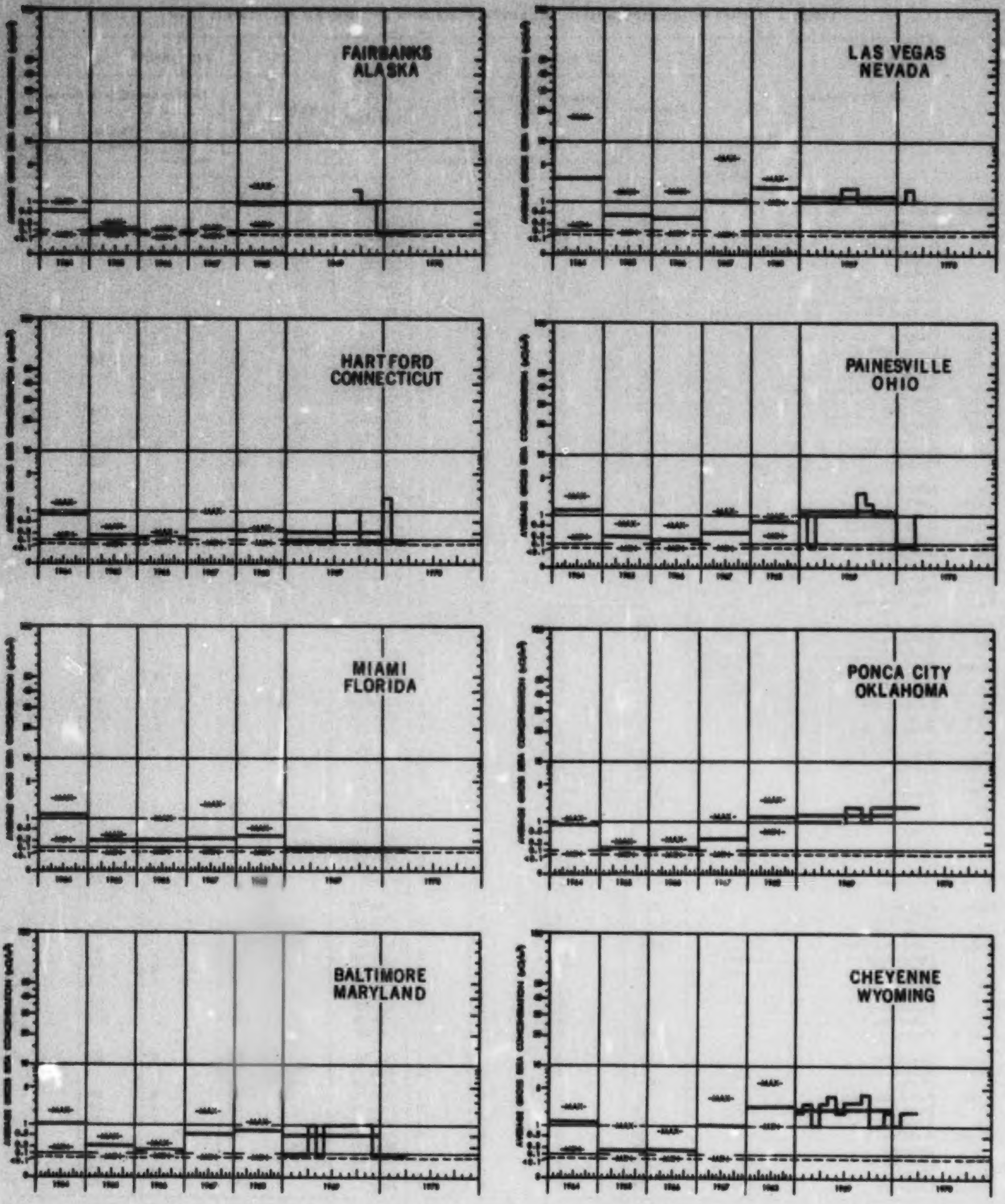

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1963-March 1970

2. Canadian Air and Precipitation Monitoring Program[1], March 1970

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports*.

Surface air and precipitation data for March 1970 are presented in table 2.

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[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, March 1970

Station	Number of samples	Air surveillance, gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	31	0.3	0.0	0.1	46	1.0
Coral Harbour	27	.2	.0	.1	84	1.2
Edmonton	31	.1	.0	.1	41	1.1
Ft. Churchill	30	.2	.1	.1	38	.7
Fredericton	30	.3	.0	.0	32	2.1
Goose Bay	31	.2	.0	.0	15	1.4
Halifax	31	.4	.0	.1	28	3.2
Inuvik	31	.1	.0	.1	25	.2
Montreal	30	.4	.0	.1	99	5.2
Moosonee	31	.3	.1	.1	11	.2
Ottawa	31	.2	.1	.1	125	6.4
Quebec	30	.3	.0	.1	35	2.9
Regina	31	.2	.0	.1	27	.4
Resolute	31	.3	.0	.1	37	.1
St. John's, Nfld	30	.2	.0	.1	38	5.2
Saskatoon	31	.2	.0	.1	1	.1
Sault Ste. Marie	30	.2	.1	.1	72	1.0
Thunder Bay	31	.2	.1	.1	34	1.3
Toronto	31	.3	.0	.1	87	4.4
Vancouver	31	.2	.0	.1	71	4.2
Whitehorse	30	.1	.0	.1	ND	.4
Windsor	31	.2	.0	.1	73	3.9
Winnipeg	31	.2	.0	.1	16	.5
Yellowknife	31	.2	.1	.1	2	.1
Network summary	733	0.4	0.0	0.1	45	1.9

ND, nondetectable.

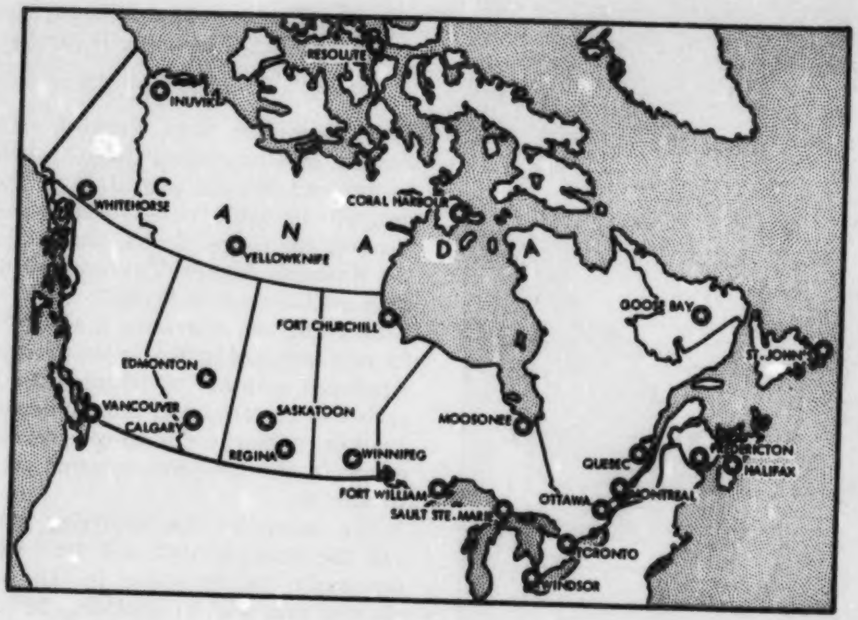
RESOLUTE
INUVIK
C A N A D A
WHITEHORSE
CORAL HARBOUR
YELLOWKNIFE
GOOSE BAY
FORT CHURCHILL
ST. JOHNS
EDMONTON
VANCOUVER
CALGARY
SASKATOON
MOOSONEE
REGINA
WINNIPEG
QUEBEC
FREDERICTON
HALIFAX
FORT WILLIAM
OTTAWA
MONTREAL
SAULT STE. MARIE
TORONTO
WINDSOR

Figure 3. Canadian air and precipitation sampling stations

3. Pan American Air Sampling Program
March 1970

Pan American Health Organization and
U.S. Public Health Service

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 4. Analytical techniques were described in the January 1968 issue of *Radiological Health Data and Reports*. The March 1970 air monitoring results from the participating countries are given in table 3.

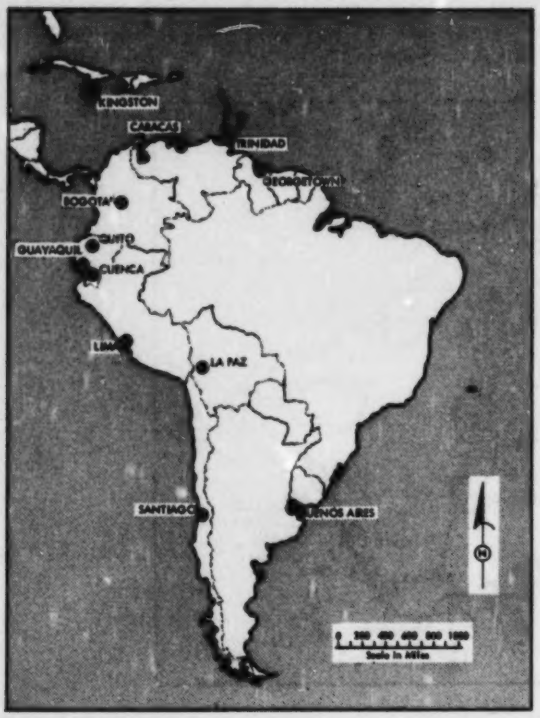

Figure 4. Pan American Air Sampling Program stations

Table 3. Summary of gross beta radioactivity in Pan American surface air, March 1970

Station		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average
Argentina:	Buenos Aires	NS	NS	NS	NS
Bolivia:	La Paz	NS	NS	NS	NS
Chile:	Santiago	30	0.14	0.02	0.08
Colombia:	Bogota	18	.14	.02	.06
Ecuador:	Cuenca	NS	NS	NS	NS
	Guayaquil	NS	NS	NS	NS
	Quito	NS	NS	NS	NS
Guyana:	Georgetown	11	.32	.05	.15
Jamaica:	Kingston	NS	NS	NS	NS
Peru:	Lima	21	.13	.04	.05
Venezuela:	Caracas	12	1.32	.01	.08
West Indies:	Trinidad	13	.24	.08	.17
Pan American summary		105	1.32	0.01	0.09

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

NS, no sample.

4. Tritium in Precipitation (RAN)
July–December 1969

Bureau of Radiological Health
U.S. Public Health Service

The Radiation Alert Network (RAN) of the Bureau of Radiological Health, Public Health Service, established a tritium in precipitation program in 1967. Nine stations were selected covering the United States, including Alaska and the Hawaiian Islands. The locations of these stations are indicated in figure 1.

Rain analysis represents a sensitive technique for monitoring of tritium in the environment. Any significant addition of tritium into the natural cycle can be easily and rapidly detected by rain analysis, primarily due to considerable improvements in the low-level counting techniques for tritium (*6*).

The procedure for analyzing these samples and the data for 1967 and 1968 were reported previously (*7*). As stated in this reference the samples were sent to Rockville, Md., composited by months and aliquots of the composite shipped to the Southeastern Radiological Health Labora-

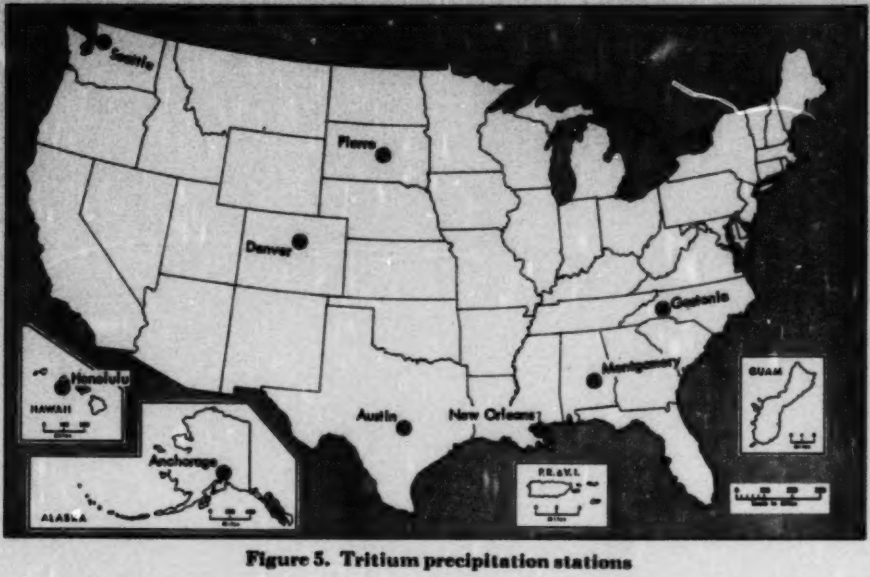

Figure 5. Tritium precipitation stations

Table 4. Tritium analysis of precipitation from RAN stations
July–December 1969

Location	Concentration (nCi/liter)					
	July	Aug	Sept	Oct	Nov	Dec
Alaska: Anchorage	NS	NS	NS	0.2	<0.2	<0.2
Ala: Montgomery	<0.2	<0.2	0.7±0.2	0.4±0.2	0.3±0.2	<.2
Colo: Denver	NS	NS	NS	.3± .2	.4± .2	<.2
Hawaii: Honolulu	NS	NS	NS	<.2	<.2	NS
La: New Orleans	NS	NS	<.2	<.2	<.2	<.2
N.C: Gastonia	NS	NS	NS	<.2	<.2	<.2
S. Dak: Pierre	NS	NS	NS	NS	NS	NS
Tex: Austin	NS	NS	NS	<.2	<.2	<.2
Wash: Seattle	NS	NS	NS	<.2	<.2	<.2

NS, no sample.

tory (SERHL). As of October 1, 1969, all samples are sent directly to SERHL and are no longer handled at Rockville, Md.

The data for the last 6 months of 1969 appear in table 4. The concentration of tritium at these stations for this period remain at the same level as previously reported.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–December 1967 and 1968	March 1970
January–June 1969	June 1970

REFERENCES

(*1*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW-RP-3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(*2*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW-RP-4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(*3*) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW-RP-5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(*4*) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD-11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(*5*) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD-21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

(*6*) MOGHISSI, A. A. Analysis and Public Health Aspects of Environmental Tritium, Radionuclides in the Environment. Advances in Chemistry Series, No. 93. American Chemical Society, Washington, D. C. (1970) pp. 419–426.

(*7*) MOGHISSI, A. A. and C. R. PORTER. Tritium concentration in precipitation, 1967–1968. Radiol Health Data Rep 11:137–140 (March 1970).

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SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for the Argonne National Laboratory and the S1C Prototype Reactor Facility.

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[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Argonne National Laboratory[2]
January–June 1969

University of Chicago
Lemont, Ill.

The radioactivity of the environment is determined on a continuing basis by measuring the radioactivity in naturally-occurring materials collected both on and off the Argonne National Laboratory site. Since radioactivity is usually spread by air and water, the environmental monitoring program at Argonne has concentrated on these materials. The sampling locations discussed in this report are shown in figures 1 and 2.

Air monitoring

Air-filter samples were collected continuously at seven locations on the Argonne site and at five locations off the site. The alpha and beta radioactivity in air-filter samples are summarized in table 1; the average concentrations of gamma-ray emitters as determined by gamma-ray spectrometry are summarized in table 2. The alpha radioactivity concentrations were due principally to naturally-occurring radionuclides and were in the range found in previous years. As in the past, much of the beta and gamma radioactivity was due to fission and neutron activation products from nuclear detonations, although about one-third of the gamma radioactivity and a smaller fraction of the beta radioactivity were due to beryllium-7, produced continuously in the upper atmosphere by cosmic-ray interactions. The variation in total beta radioactivity during the year can be correlated with the concentrations of the individual gamma-ray emitters. The steady increase in total beta radioactivity from January to June 1969 can be correlated with the concentrations of the individual gamma-ray emitters. All the gamma-ray emitters for which positive results were obtained, including the naturally-occurring beryllium-7, increased in concentration from March through June 1969. This behavior

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[2] Summarized from "Environmental Radioactivity at Argonne National Laboratory, January–June 1969," University of Chicago, Lemont, Ill.

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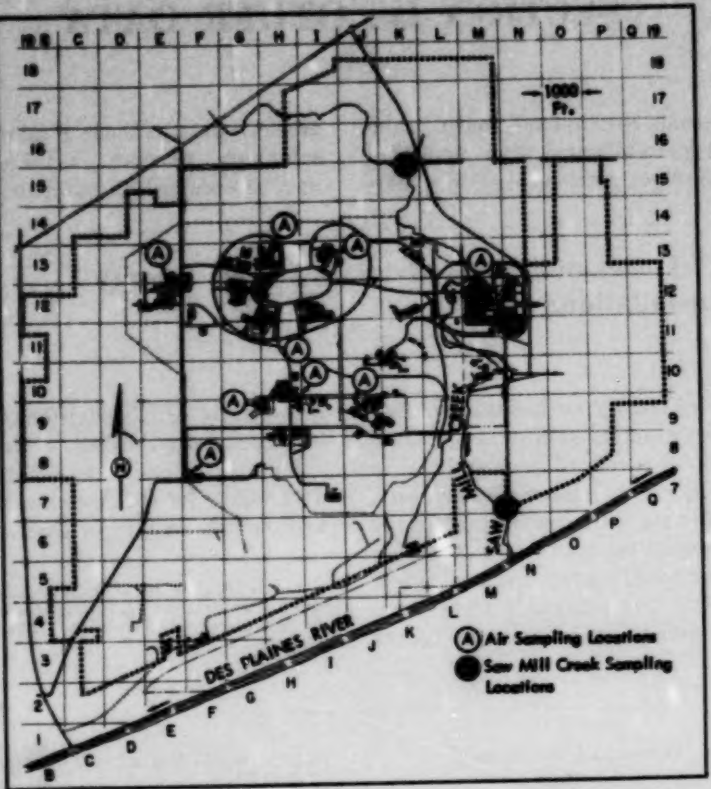
1000 Ft.
DES PLAINES RIVER
SAW MILL CREEK
Air Sampling Locations
Saw Mill Creek Sampling Locations

Figure 1. Onsite sampling locations at Argonne National Laboratory

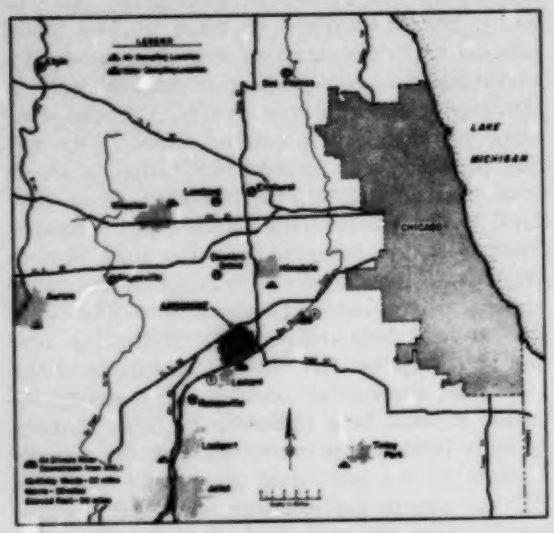
LEGEND
LAKE MICHIGAN
CHICAGO
ARGONNE

Figure 2. Location of Argonne National Laboratory (including some offsite sampling stations)

is attributed to the usual "spring maximum" in stratospheric fallout. Most of the fission products in the samples were injected into the atmosphere several months before they were observed, probably about December 1968, since the shortest-lived fission product detected in the spring was cerium-141 and the most abundant fission products were zirconium-95 and niobium-95. The presence of a very small amount of barium-140 (~1 fCi/m^3) in the air during the middle of January supports the suggestion that most of the fission product fallout originated in December 1968. The delay in its appearance implies high-altitude injection, or possibly an increased spring fallout rate from the troposphere by rain washout.

The average beta radioactivity during the first half of 1969 was very similar to 1968, as were the relative abundances of the fission products. Zirconium-niobium-95 was the predominant fission product during both periods.

Table 1. Alpha and beta radioactivity in air-filter samples[a], Argonne, January–June 1969

Period	Location	Number of samples	Alpha radioactivity (fCi/m³)			Beta radioactivity (pCi/m³)		
			Average	Minimum	Maximum	Average	Minimum	Maximum
January	Onsite	30	2.3	0.9	4.4	0.07	0.04	0.10
	Offsite	25	3.0	1.2	5.1	.08	.06	.15
February	Onsite	23	3.3	2.0	5.5	.10	.05	.17
	Offsite	18	3.0	2.6	7.2	.11	.07	.16
March	Onsite	24	3.8	1.8	5.6	.13	.08	.20
	Offsite	20	4.4	3.2	8.9	.18	.12	.61
April	Onsite	27	3.8	2.3	5.9	.18	.09	.26
	Offsite	23	4.3	2.7	7.1	.21	.14	.40
May	Onsite	24	3.9	1.6	8.1	.21	.16	.52
	Offsite	21	4.1	.5	7.6	.33	.06	.54
June	Onsite	24	3.3	.7	5.8	.34	.12	.52
	Offsite	23	4.0	2.5	6.6	.39	.20	.55
Summary	Onsite	152	3.4	0.7	8.1	0.19	0.04	0.52
	Offsite	130	4.0	0.5	8.9	0.22	0.06	0.61

[a] These results were obtained by measuring the samples 4 days after they were collected in order to avoid counting the natural radioactivity due to radon and thoron decay products.

Table 2. Gamma-ray radioactivity in air-filter samples, Argonne, January–June 1969

Radionuclide	Location	Concentration (pCi/m³)						
		January	February	March	April	May	June	Average
Barium-lanthanum-140	Onsite	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Offsite	< .01	< .01	< .01	< .01	< .01	< .01	< .01
Beryllium-7	Onsite	.06	.05	.07	.06	.08	.11	.08
	Offsite	.05	.04	.07	.10	.09	.12	.08
Cerium-141	Onsite	< .01	< .01	< .01	.01	.02	.02	.01
	Offsite	< .01	< .01	< .01	.01	.02	.02	.01
Cerium-144	Onsite	< .01	.01	.02	.02	.03	.04	.02
	Offsite	< .01	.01	.02	.02	.03	.05	.02
Cesium-137	Onsite	< .01	< .01	< .01	< .01	< .01	< .01	< .01
	Offsite	< .01	< .01	< .01	< .01	< .01	< .01	< .01
Iodine-131	Onsite	< .01	< .01	< .01	< .01	< .01	< .01	< .01
	Offsite	< .01	< .01	< .01	< .01	< .01	< .01	< .01
Ruthenium-103	Onsite	< .01	< .01	.01	.01	.03	.03	.02
	Offsite	< .01	< .01	.01	.02	.03	.03	.02
Ruthenium-rhodium-106	Onsite	.02	.03	.05	.06	.06	.07	.05
	Offsite	.02	.02	.05	.07	.07	.08	.05
Zirconium-niobium-95	Onsite	< .01	< .01	.01	.03	.07	.11	.04
	Offsite	< .01	< .01	.01	.04	.08	.13	.05

The same fission products detected in the air-filter samples were also present in precipitation samples, and the beta and gamma radioactivities of these samples also increased during the spring months. Large volume rain samples were collected monthly and analyzed for iron–55. The average monthly concentrations ranged from 39 to 890 pCi/m² of surface. The average, 300 pCi/m², was six times higher than the previous 6-month period, principally because of one large value in in June 1969 (890 pCi/m²). Iron–55 is a neutron activation product and was produced mainly in nuclear tests conducted in September and October 1961. Therefore, the above concentrations have been corrected for decay to October 15, 1961, for comparison purposes. Except for May, the iron–55 concentrations also show a "spring maximum". The neutron activation products, tungsten–181–185, were also detected in some of the rain samples.

Air sampling for argon–41, a beta-particle emitter with a 1.8 hour half-life produced in an operating reactor by the action of neutrons on the stable argon in air, was conducted near the Juggernaut reactor (building 335) from March through June. The results are tabulated in table 3. These concentrations are based on 1-minute grab samples taken at a position downwind from the reactor at a point favorable for argon–41 detec-

Table 3. Argon-41 concentrations near Juggernaut reactor March–June 1969

Month	Number of samples	Number of samples >20 nCi/m³	Concentration[a] (nCi/m³)		Percent of AEC standard	
			Average	Maximum	Average	Maximum
March	6	0	—	<20	—	<50
April	22	12	43	133	110	330
May	24	11	33	140	83	350
June	28	11	21	88	53	220
Summary	80	34	27	140	70	350

[a] Minimum detectable concentration—20 nCi/m³.

tion after the reactor had been in operation for several hours. Therefore, the actual average concentration per 24-hour day in the vicinity of the reactor was much less than the values in the table. The argon-41 concentration in the exhaust from the Juggernaut is about 260 µCi/m³, so the average dilution by outside air in the samples collected was about a factor of 1,000. In 1968, argon-41 concentrations were measured in the vicinity of the CP-5 reactor (building 330), which operates at a power level about 20 times higher than Juggernaut. The CP-5 reactor is undergoing rehabilitation and is not being operated this year. A comparison of the argon-41 concentration near the two reactors is of interest. In 1968, argon-41 was detected in about 46 percent of the samples collected near CP-5. The average concentration was 140 nCi/m³. The fraction of positive results near the Juggernaut reactor was quite similar, 43 percent, while the average concentration, 27 nCi/m³, was five times smaller. In the CP-5 reactor the air that is exposed to neutrons is diluted with a large volume of inactive air before it is discharged. This means that the argon-41 concentrations in the air leaving the two reactor buildings are not greatly different, although the volume of air (containing argon-41) is about 15 times greater from CP-5. As a result, the argon-41 concentration in outside air averaged only five times less near the Juggernaut although the argon-41 production is about 20 times less than CP-5.

Air was sampled for tritiated (hydrogen-3) water vapor 50 yards west of the CP-5 reactor by absorbing the water vapor from the air on silica gel. The silica gel was heated to collect the water, whose tritium content was measured. The results are given in table 4. The results were positive in all but a few samples, although the concentrations were well below the AEC standards. This nuclide is produced continuously while the reactor is in operation by the action of neutrons on the heavy water used for moderating and cooling. Although the reactor has not been in operation since January 1969, the heavy water containing the long-lived tritium was handled while the reactor was dismantled, and a small quantity evidently did escape from the building. The average concentration this year, 185 pCi/m³, was about 30 percent higher than during 1968. Samples were also collected in the east area, 1,829 meters (2,000 yards) from the reactor, during May. These had an average tritium concentration of 12 pCi/m³, compared to 208 pCi/m³ for samples collected

Table 4. Tritium concentrations near CP-5 reactor, January–June 1969

Month	Number of samples	Concentration (pCi/m³)			Percent of AEC standard	
		Average	Minimum	Maximum	Average	Maximum
January	6	286	130	504	0.14	0.25
February	14	109	14	470	.05	.24
March	9	228	12	710	.11	.36
April	16	122	<10	549	.06	.27
May	15	208	<10	998	.10	.50
June	16	156	23	788	.08	.39
Summary	76	185	<10	998	0.09	0.50

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near the reactor during the same period. The concentration in the east area samples ranged from less than 10 to 21 pCi/m³, and was greater than 10 pCi/m³ only on days when the concentration near the reactor was more than 100 pCi/m³. The highest value, 21 pCi/m³, was obtained on the day when the concentration near the reactor was also a maximum, 898 pCi/m³. The correlation is sufficiently good to conclude that the positive results in the east area samples were real and the result of tritium from the CP-5 reactor.

Water monitoring

Argonne wastewater is discharged into Sawmill Creek, a small stream that runs through the Argonne grounds and enters the Des Plaines River about 500 yards downstream from the wastewater discharge. Sawmill Creek was sampled upstream from the Argonne site and downstream from the wastewater outfall to determine if radioactivity was added to the stream from Argonne wastewater. The sampling locations are shown in figure 2.

Below the wastewater outfall the creek was usually sampled three times weekly except when five continuous sequential samples were collected for 5 weeks. Since it was impractical to analyze all the samples for all the radionuclides and elements desired, equal portions of the individual samples collected each week were combined and analyzed. The results obtained in this way represent the average concentrations in the weekly samples. Above the site, samples were collected twice monthly and at least one sample each month was analyzed for each radionuclide of interest. The total alpha and beta radioactivities found in Sawmill Creek during January–June 1969 are given in table 5. Upstream from the Argonne site, the alpha activity was due primarily to radioactive nuclides that occur naturally in the stream and was in the normal range. Any additional radioactivity downstream was due to alpha-emitting nuclides in the wastewater. The concentration of alpha radioactivity in the creek resulting from the presence of Argonne wastewater can be estimated as follows.

The ratio of creek water to Argonne wastewater ranged from about 1 to 10 during the first half of 1969. This increased dilution above previous years is due to the discharge into the creek of water from a new public sewage disposal plant north of the laboratory. Consequently, the natural alpha radioactivity in the creek below the outfall varied from 50 to 90 percent of the upstream concentration and the alpha radioactivity (primarily uranium) added by Argonne wastewater varied from 0.9 pCi/liter, when the dilution factor was one, to less than 0.1 pCi/liter when the dilution factor was about ten. Although some alpha radioactivity was added to the creek in Argonne wastewater, the amounts were not large enough to increase the total alpha radioactivity in the steam above the normal range, and on some days the wastewater evidently contained less alpha radioactivity than upstream water.

The alpha-particle emitters most likely to be present in Argonne wastewater are isotopes of uranium, plutonium, and thorium. The alpha

Table 5. Non-volatile alpha and beta radioactivity in Sawmill Creek water, Argonne, January-June 1969

Month	Location[a]	Number of samples	Alpha radioactivity (pCi/liter)			Beta radioactivity (pCi/liter)		
			Average	Minimum	Maximum	Average	Minimum	Maximum
January	Upstream	2	3.4	3.2	3.6	11	11	11
	Downstream	14	2.2	1.5	2.6	12	9.0	16
February	Upstream	2	2.2	1.8	2.5	9.4	8.1	11
	Downstream	14	2.5	2.1	3.1	13	11	16
March	Upstream	2	3.9	3.3	4.5	15	13	17
	Downstream	12	2.9	1.7	3.6	14	10	18
April	Upstream	2	2.0	1.7	2.3	10	10	11
	Downstream	14	2.1	1.9	2.2	9.4	8.7	10
May	Upstream	2	1.9	1.5	2.2	11	8.8	14
	Downstream	25	1.7	1.2	2.5	12	9.5	14
June	Upstream	2	3.4	2.6	4.1	19	7.9	31
	Downstream	14	2.3	1.2	3.6	13	8.7	23
Summary	Upstream	12	2.8	1.5	4.5	13	7.9	31
	Downstream	93	2.3	1.2	3.6	12	8.7	23

[a] Relative sampling location with respect to Argonne wastewater outfall (figure 1).

Table 6. Alpha-emitting elements in Sawmill Creek water, Argonne January–June 1969

Element	Location[a]	Number of samples	Concentration (pCi/liter)			Percent of AEC standard	
			Average	Minimum	Maximum	Average	Maximum
Uranium	Upstream	6	1.7	1.2	2.6	0.004	0.007
	Downstream	40	1.8	.9	2.9	.005	.007
Plutonium	Upstream	6	—	—	<.05	—	<.001
	Downstream	40	—	—	<.05	—	<.001
Thorium	Upstream	6	—	—	<.05	—	<.003
	Downstream	40	—	—	<.05	—	<.003

[a] Relative sampling location with respect to Argonne wastewater outfall (figure 1).

radioactivity in the creek water due to these elements are summarized in table 6.

In addition to the natural beta radioactivity in the creek, beta radioactivity from nuclear detonations was detected at both sampling locations and beta radioactivity from Argonne wastewater was found in some samples below the outfall. The natural beta radioactivity is approximately 5 pCi/liter above the site and 2 to 5 pCi/liter below the site depending on the dilution by wastewater. The Argonne contribution to the total nonvolatile beta radioactivity below the outfall during the first half of 1969 is estimated to be approximately 2 pCi/liter compared to 7 pCi/liter in 1968. The remaining activity at both locations, 5 to 8 pCi/liter, was due to fallout. The concentration of fallout activity was about two-thirds that found during 1968.

The results of analysis of Sawmill Creek water for specific beta-emitting nuclides are summarized in table 7. The principal beta-particle emitter added to the creek by Argonne wastewater was tritium. This radionuclide, present as water (HTO), is not included in the total beta activity in table 5 since the latter radioactivity was determined by evaporating the water and measuring the nonvolatile residue. Separate samples were analyzed specifically for tritium. Although some of the cesium–137, tritium, and strontium–90 were added to the creek by fallout, the total concentration, regardless of source, must be used in assessing the health hazard of a radioactive nuclide

Table 7. Beta-emitters in Sawmill Creek water, Argonne, January–June 1969

Radionuclides	Location[a]	Number of samples	Beta radioactivity (pCi/liter)			Percent of AEC standard	
			Average	Minimum	Maximum	Average	Maximum
Barium-140	Upstream	6	—	—	<2	—	<0.007
	Downstream	48	—	—	<2	—	< .007
Cerium-144	Upstream	12	—	—	<10	—	< .1
	Downstream	93	—	—	<10	—	< .1
Cesium-137	Upstream	6	0.5	<0.5	1.2	0.003	.006
	Downstream	93	.8	< .5	2.3	.004	.012
Cobalt-58	Upstream	12	—	—	< 5	—	< .005
	Downstream	93	—	—	< 5	—	< .005
Cobalt-60	Upstream	12	—	—	< 3	—	< .006
	Downstream	93	—	—	< 3	—	< .006
Tritium	Upstream	6	740	400	1,160	.025	.039
	Downstream	93	7,490	440	69,700	.25	2.3
Iodine-131	Upstream	—	—	—	—	—	—
	Downstream	93	—	—	< 3	—	<1
Strontium-89	Upstream	6	—	—	< 2	—	< .07
	Downstream	48	—	—	< 2	—	< .07
Strontium-90	Upstream	6	1.9	1.1	2.6	.6	.9
	Downstream	48	1.5	< .5	3.1	.5	1.0
Technetium-99	Upstream	6	—	—	< .5	—	< .0002
	Downstream	93	< .5	< .5	1.0	< .0002	.0003
Thorium–protactinium-234	Upstream	6	1.4	1.0	2.1	.007	.011
	Downstream	40	1.4	.7	2.3	.007	.012

[a] Relative sampling location with respect to Argonne wastewater outfall (figure 1).

not naturally present in the environment. The percent of the AEC standard given in the table was calculated on this basis. As indicated in the table, the beta radioactivities in the creek were very low compared to the AEC standards.

Since Sawmill Creek empties into the Des Plaines River, which in turn flows into the Illinois River, the radioactivity in the latter two streams is important in assessing the contribution of Argonne wastewater to the environmental radioactivity. The Des Plaines River was sampled monthly above the mouth of Sawmill Creek and weekly below the mouth to determine if the radioactivity in the creek had any effect on the radioactivity in the river. The total radioactivity is summarized in table 8, and the results of analysis for specific elements and radionuclides are given in table 9.

Table 8. Average radioactivity in Des Plaines and Illinois River water, ANL, January–June 1969

Location	Concentration (pCi/liter)			
	Non-volatile alpha radioactivity	Uranium	Non-volatile beta radioactivity	Tritium
Des Plaines River[a] (above Sawmill Creek)	3.4	1.9	10	460
Des Plaines River[b] (below Sawmill Creek)	3.0	1.8	12	4,110
Illinois River[c]	3.6	2.8	9	<400

[a] Sampled near Route 45, upstream from the mouth of Sawmill Creek.
[b] Sampled near Lemont, downstream from the mouth of Sawmill Creek.
[c] One sample collected on June 19 at McKinley Woods opposite the Dresden Nuclear Power Plant.

Tritium was the only radionuclide whose concentration was higher below the mouth of Sawmill Creek, and the additional activity at this location evidently originated in Argonne wastewater. However, the average and maximum concentrations below the creek amounted to only 0.13 and 1.1 percent, respectively, of the AEC standards. The concentration of tritium in the river above the creek is similar to that found last year in the Des Plaines River and to that found in other streams in the area. This nuclide occurs naturally and is also present in debris from nuclear tests.

The concentrations of the other radionuclides and of the total alpha and beta radioactivities were in their normal ranges at both locations. The average beta radioactivity decreased by about 25 percent from 1968. The natural nonvolatile beta radioactivity in the river is 5 to 10 pCi/liter, and any excess was due to fallout. The Illinois River was sampled at McKinley Woods on June 19, and the alpha, beta, uranium, and tritium radioactivities (3.6, 9.0, 2.8, and < 400 pCi/liter, respectively) were normal and similar to those found in other streams in the area. No evidence of radioactivity from Argonne was detected.

Radioactivity in milk

Raw milk was collected monthly from a local dairy farm and analyzed for several fission products. Strontium–89, iodine–131, and barium–140

Table 9. Radioactivity in Des Plaines River water, Argonne January–June 1969

Radionuclide	Location[a]	Number of samples	Concentration (pCi/liter)		
			Average	Minimum	Maximum
Barium-140	Upstream	2	—	—	<2
	Downstream	5	—	—	<2
Cerium-144	Upstream	6	—	—	<10
	Downstream	26	—	—	<10
Cobalt-58, -60	Upstream	6	—	—	<10
	Downstream	26	—	—	<10
Tritium	Upstream	3	460	400	830
	Downstream	12	4,110	400	32,400
Plutonium (alpha)	Upstream	3	—	—	<.05
	Downstream	6	—	—	<.05
Strontium-89	Upstream	2	—	—	<2
	Downstream	5	—	—	<2
Strontium-90	Upstream	2	1.9	1.2	2.6
	Downstream	5	1.6	1.2	2.4
Thorium (alpha)	Upstream	3	—	—	<.05
	Downstream	6	—	—	<.05
Thorium–protactinium-234	Upstream	1	—	—	1.5
	Downstream	6	1.4	1.0	1.9
Uranium (alpha)	Upstream	1	—	—	1.9
	Downstream	6	1.8	1.3	2.4

[a] Relative sampling location with respect to Argonne wastewater outfall (figure 1).

were not present in concentrations greater than the minimum detectable amounts of 20 pCi/liter for iodine–131 and 3 pCi/liter for the other two radionuclides. The strontium–90 and cesium–137 concentrations are given in table 10. These two radionuclides are long-lived fission products from past nuclear tests and their presence in milk is not related to Argonne operations. The cesium–137 concentrations during the first half of 1969 decreased to one-half of the 1968 concentrations, while the strontium–90 concentrations were nearly the same.

Table 10. Fission product concentrations in milk January–June 1969

Date collected	Concentrations (pCi/liter)	
	Cesium-137	Strontium-90
January 2	17	6.3
February 5	16	2.1
March 5	16	6.2
April 2	15	5.2
May 8	30	5.2
June 3	12	7.3
Average	18	5.4

Conclusion

Argonne's contribution to the environmental radioactivity was primarily limited to tritium and argon–41 in the air and to tritium in water from Sawmill Creek and the Des Plaines River. The only radioactivity detected off the site was the tritium in the two streams. The concentrations were low and did not constitute a health hazard.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1968	May 1969
July–December 1968	February 1970

2. S1C Prototype Reactor Facility[3]
January–December 1968

Combustion Engineering, Inc.
Windsor, Conn.

The S1C Prototype Reactor Facility is a land-based nuclear submarine power plant operated for the Atomic Energy Commission by the Naval Reactors Division of Combustion Engineering, Inc. The prototype contains a pressurized water reactor power plant which is used to conduct research and development work and to train personnel in the operation of naval reactor power plants. Reactor power operations at the S1C Prototype Facility began in December 1959.

The low level radioactive waste discharged intermittently from S1C prototype operations consist mainly of water. Small quantities of airborne particulates in gaseous waste are also generated and released on occasion in the ventilation exhaust air.

Essentially, all of the radioactive waste originates from the activation of minute amounts of impurities or corrosion products in the circulating water used as a reactor coolant. All materials released to the environment are routinely monitored to assure that waste disposal operations comply with AEC regulations.

Air monitoring

Ventilation air from the submarine hull and the supporting facility at the prototype site may contain small amounts of radioactive gases or particulates. This ventilation air is discharged to the environment through an exhaust stack. The ventilation air is continuously monitored for radioactivity by automated counters which control the discharge of the exhaust air. When the AEC maximum permissible concentration limits are exceeded, the exhaust air is discharged through a high-efficiency filter bank or the ventilation system is completely shut down and the hull sealed. In addition, air is continuously sampled for particulates at onsite and offsite locations shown in figure 3.

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[3] Summarized from "S1C Prototype Reactor Facility Environmental Monitoring, Report for 1968."

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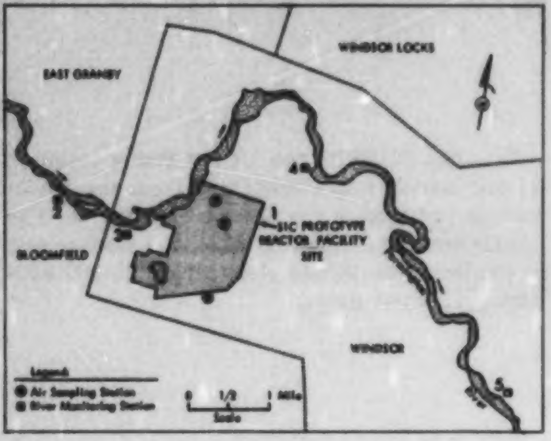

Figure 3. Environmental monitoring locations, S1C prototype site

Liquid radioactive waste

Drainage from all systems which are known to contain radioactive liquids was collected, processed and sampled prior to discharge to the environment to assure that discharge concentrations were within the required limits. In addition, waste effluent is sampled as it is discharged to the environment. These samples are analyzed for radioactivity and the results are retained as part of the permanent records.

The S1C Prototype discharged a total of 1.81 megaliters of radioactive liquid waste containing 511.8 microcuries of radioactivity during 1968 for an annual average discharge concentration of 280 pCi/liter.

Water monitoring

Water and sediment samples from the Farmington River are taken quarterly and analyzed. These samples are used to determine if buildup (reconcentration of radioactivity) is occurring.

The Farmington River was sampled at the outlet of the S1C Prototype discharge brook. During 1968, gross gamma radioactivity of water samples from the outlet of the S1C discharge brook ranged from 24 to 44 pCi/liter which is well below the 30 nCi/liter maximum permissible concentration specified by the Federal Regulations for cobalt-60, the most limiting radionuclide in S1C wastes. In 1967, the techniques used to analyze for radioactivity in water samples were changed from beta-particle to gamma-ray counting. This provides better detection of small changes in radioactivity levels.

Airborne radioactivity

All areas on site where gaseous and/or particulate airborne radioactivity could be present are directed through ducts to monitored stacks. The stacks are monitored for airborne levels on a continuous basis. The facility's operational controls ensure that the radioactive concentration in the environment does not exceed the 100 pCi/m^3 limit. This limit is based on the assumption that levels of strontium-90 and alpha-particle emitting isotopes are insignificant.

The airborne particulate radioactivity samples taken during discharge are recounted 4 hours after discharge. This delay allows short-lived radioactivity to decay. The air effluent analysis records indicate that no significant airborne radioactivity was discharged above natural background levels.

Conclusions

Results of the analyses and of the continuous monitoring throughout 1968 have indicated that S1C Prototype operations have met all of the Federal Regulations pertaining to AEC standards. Environmental analyses indicate that no significant quantities of radioactivity have accumulated above the preoperational environmental results. It is, therefore, concluded that the facility operations have not adversely affected the surroundnig environment.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–December 1967	March 1969

Reported Nuclear Detonations, June 1970

(Includes seismic signals from foreign test areas)

The U.S. Atomic Energy Commission announced only one nuclear test for June 1970. A nuclear test of low-intermediate yield (20–200 kilotons TNT equivalent) was conducted underground on June 26, 1970, by the Atomic Energy Commission at its Nevada Test Site.

On June 27, 1970, the United States recorded seismic signals which originated from the Soviet nuclear test area in the Semiplatinsk region. The signals were equivalent to those of a nuclear test in the low-intermediate yield range (20–200 kilotons TNT equivalent).

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 11, Number 8, August 1970

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the Bureau of Radiological Health, Public Health Service.

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Reports

A Priority System for the Inspection of X-Ray Facilities

Bobby L. Dillard and Charles M. Hardin[1]

A method of establishing a priority system for performing radiation safety inspections of specific x-ray facilities in Kentucky by a State radiation control program is described. Data obtained from past inspections of radiographic, fluoroscopic and dental x-ray facilities are evaluated, and a priority number is assigned to these facilities. Those facilities with the highest priority number will be surveyed first on the next round of inspections.

It is well established that x rays, particularly medical and dental x rays, contribute the largest unnecessary exposure to the population of any man-made source of ionizing radiation. It is the primary objective of any radiation control program to reduce this unnecessary exposure to the lowest practicable level without hindering the beneficial use of this invaluable tool.

Since the immediate impact of reducing radiation exposure to the population is not readily apparent as with other fields of public health, it is necessary to evaluate this impact by some other means. State radiological health programs are constantly faced with the problem of evaluating the effectiveness of their programs in improving the health of the population by their particular service.

Any method or system that a program uses to perform the evaluation of its effectiveness must consist of three distinct processes:

(1) A method of evaluation, based on the need for the specific service, must provide for establishing priorities, with the benefit of such service being the maximum for each dollar spent;

(2) The method should provide a mechanism to guide the program to reach its objective;

(3) The method must show that the activities performed by the program are based on the greatest need for the greatest number of people.

In the fall of 1968, the Kentucky Radiological Health Program initiated a system of establishing priorities for performing x-ray inspections throughout the state. This system provided the Kentucky Radiological Health Program with a method of evaluating the effectiveness of the program activities in accomplishing its objective of reducing x-ray exposure to the population. It is felt that the system used in Kentucky can be adopted, possibly with minor modifications, for radiation control programs of other States as well.

Priority system

Over the years, several methods have been used to establish the frequency of x-ray inspections. However, none of these methods seems to effectively combine deficiencies found during past in-

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spections with the number of people exposed, in a manner which would make it possible to determine the frequency of inspection required. Since the major objective of a radiation control program is to offer its service to the maximum number of people, the system which has been developed combines these two factors (deficiency of the x-ray machine and the number of people exposed by the x-ray machine) to establish a facility priority number.

In certain instances, there may be geographical, economical, occupational or other conditions that require special attention. Although the population affected may be small, the potential problem may be great. Under these circumstances, it may be necessary to deviate from, or even ignore, the priority number established.

The described system does not provide a priority number for medical therapeutic, industrial, or veterinarian x-ray facilities. The system specifically provides a priority number for medical, chiropractic, and dental x-ray facilities. In Kentucky, medical therapeutic, industrial, and veterinarian x-ray facilities represent less than 4 percent of the total registered x-ray facilities. In addition, their mode of operation differs so significantly from medical, chiropractic, and dental x-ray use that it is very difficult, if not impossible, to establish one system to cover all disciplines. With industrial and veterinarian x-ray facilities, only the operator is exposed—human patients not being a factor. With medical therapeutic x-ray facilities, the consideration for human patient exposure is entirely different than that for radiographic exposures. In the future, it is proposed to establish a priority system for these disciplines as well.

To arrive at the appropriate facility priority number, each machine in a given facility is handled individually. Tabulated in tables 1, 2 and 3 are debit points which are assigned to deficient items for radiographic, fluoroscopic and dental x-ray machines, respectively. These debit points were determined by relating the items with respect to their importance in reducing unnecessary radiation exposure. Both the operator and the patient were considered.

In the tables, each item is a positive question. The debit points given for each item are considered only if the machine does *not* have or use the item in question.

Table 1. Debit points for radiographic machines not meeting stated criteria

Criteria	Debit points
Operating personnel:	
Registered technician	3
Trained and experienced operators	6
Personnel monitoring system	3
Film and screen:	
Film speed (fast)	3
Type of intensifying screen (fast)	3
Darkroom:	
Adequate darkroom (clean, light-tight, etc.)	2
Automatic process or thermometer used	2
Timer used	2
Filtration and collimation:	
Proper filtration for kVp used	20
Rectangular variable aperture light-finding collimator	5
Adequate collimation	25
Timer:	
Deadman exposure switch	1
Adequate timer	3
Protective devices:	
Gonadal shield (primary)	3
Gonadal shield (secondary)	3
Adequate operator protection	5
Adequate primary and secondary barriers	6
Diagnostic type tube housing	5

The data obtained from past inspections are evaluated and assigned debit points obtained from the tables. It is important to emphasize again that the debit points are assigned only when the machine or facility does *not* meet criteria in question. If the machine meets the criteria, no points are assigned.

After the debit points are assigned, they are totaled. This total is then multiplied by the total

Table 2. Debit points for fluoroscopic machines not meeting stated criteria

Criteria	Debit points
Operating personnel:	
Radiologist	6
Personnel monitoring system	3
Equipment:	
Image intensifying device	4
Accessory shielding:	
Leaded gloves	2
Leaded apron	3
Bucky grid slot cover	1
Leaded drapes around screen	1
Dark adaptation:	
Adequate dark adaptation	3
Usual operating procedures:	
Amperage, <5 mA	4
Time, <5 minutes	4
Screen:	
Screen ganged to x-ray tube	5
Screen cannot rotate out of beam	4
Leaded glass satisfactory	2
Shutters function properly	1
Useful beam limited to screen	10
Distance:	
15 inches from target to panel	3
Roentgen output:	
Output <10 R/min at panel surface	5
< 5 R/min at panel surface	5
Filtration:	
Proper filtration for kVp used	10
Timer:	
Deadman exposure switch	1
Manually reset cumulative timer	2
Fluoroscopic room:	
Light-tight	1

Table 3. Debit points for dental machines not meeting stated criteria

Criteria	Debit points
Operating personnel:	
Trained and experienced operator	6
Personnel monitoring system	3
Film:	
Film speed (speed group, D or greater) (1)	7
Darkroom:	
Adequate darkroom (Clean, light-tight, etc.)	2
Thermometer used	2
Timer used	2
Pointer cone:	
Open end	2
Filtration and collimation:	
Proper filtration[f] or kVp used	20
Adequate collimation	30
Timer:	
Adequate timer	3
Deadman exposure switch	1
Stability of tubehead:	
Tubehead stable	3
Protective devices:	
Diagnostic type tube housing	4
Adequate operator protection	6
Gonadal shield (secondary)	3
Adequate primary and secondary barriers	6

Table 4. Average workloads

Type of practice	Films per examination
Private practice radiologists	[a]3.0
Private practice	[a]1.8
Hospital	[a]2.6
Clinic	2.5
Mobile	1.4
Other	2.0
Dental	[a]4.2

[a] Obtained from reference 2.

radiographic or dental exposures made per week for the machine in question. If the number of exposures has not been determined, but the number of patients exposed per week is known, the films per examination listed in table 4 may be used.

For fluoroscopic machines, an additional factor of 10 is used to compensate for the difference in the low number of milliampere-seconds used for radiographic examinations as opposed to the high number of milliampere-seconds used for fluoroscopic examinations.

The product obtained by the multiplication of the debit points and the exposures per week with the additional factor of 10 for fluoroscopic machines may be large and cumbersome; therefore, this product is divided by 100.

Radiographic and dental formula:

$$\text{Priority number} = \frac{\text{Total debit points} \times \text{exposures per week}}{100}$$

Fluoroscopic formula:

$$\text{Priority number} = \frac{\text{Total debit points} \times \text{examinations per week} \times 10}{100}$$

The priority number obtained above represents a number for a specific machine. If the facility has only one machine, this number also represents the facility priority number. When the facility has more than one machine, the priority numbers for all machines are added, and the total obtained is used as the facility priority number.

Examples of using the system are as follows:

1. A dental office with one machine having a workload of 100 exposures per week was found to have the following deficient items:

Item	Debit points assigned
(a) No monitoring system	3
(b) No open end cone	2
(c) No gonadal apron	3
Total	8

In the formula:

$$\text{Priority number} = \frac{8 \times 100}{100} = 8.0$$

2. A clinic, physician's office or chiropractic office with one radiographic machine and with a workload of 20 exposures per week was found to have the following deficient items:

Item	Debit points assigned
(a) Operator not a registered technician	3
(b) Medium speed film used	3
(c) Circular cones used (rectangular variable aperture light finding collimator not used)	5
(d) No gonadal apron or protective cup	6
Total	17

In the formula:

$$\text{Priority number} = \frac{17 \times 20}{100} = 3.4$$

3. A private physician's office has a combination radiographic-fluoroscopic unit. The number of radiographic exposures per week is unknown, but 100 patients are radiographed per week. Five fluoroscopic examinations per week are performed. In addition, two spot radiographic films are made per fluoroscopic examination.

For the radiographic machine, the following deficiencies were found:

Item		Debit points assigned
(a) No monitoring system		3
(b) No thermometer		2
(c) Beam diameter—30 inches:		
No rectangular variable aperture light-finding collimator	5	
No adequate collimation	25	
		30
Total		35

Note: 100 patients × 1.8 films per examination (table 4) = 180 exposures per week.

In the formula:

$$\text{Priority number} = \frac{35 \times 180}{100} = 63.0$$

For the fluoroscopic machine, the following deficiencies were found:

Item	Debit points assigned
(a) No monitoring system	3
(b) No image intensifying device	4
(c) Milliamps used — 5 mA	4
(d) Table top exposure rate—11 R/min	10
Total	21

In the formula:

$$\text{Priority number} = \frac{21 \times 5 \times 10}{100} = 10.5$$

For the fluoroscopic machine used as a radiograph during spot films, the following deficiencies were found:

Item	Debit points assigned
(a) No monitoring system	3
(b) No thermometer	2
Total	5

In the formula:

$$\text{Priority number} = \frac{5 \times 10}{100} = 0.5$$

For the facility priority number, the machine priority numbers are totaled.

Facility priority number = 63 + 10.5 + 0.5
= 74.0

Evaluation of system

Facilities with high priority numbers are grouped together. X-ray inspections are performed, giving preference to these particular high priority facilities. Since this system combines the deficient items with the number of people exposed, it is felt that this priority system serves as a method to assure that the greatest number of people receives the service the program offers and that the benefit of this service is at the maximum for each dollar spent.

In regard to evaluating the effectiveness of a radiation control program, the priority system can also serve as a useful "measuring stick". Figures 1 through 4 show graphically the distribution of facility priority numbers for dentists, physicians, hospitals and chiropractors, respectively. The data presented in these graphs were tabulated on x-ray inspections performed by the Kentucky Radiological Health Program from January 1967 to June 1969. Five hundred and seventy-nine facilities were evaluated, representing 25 percent of the total registered facilities in Kentucky.

Although these figures show that disciplines may fall into priority groups, the important point to observe is that there are some individual facilities which have very high priority numbers. Therefore, this system indicates that inspection frequencies cannot be established on disciplines as a group but must be evaluated on the merits of each specific facility.

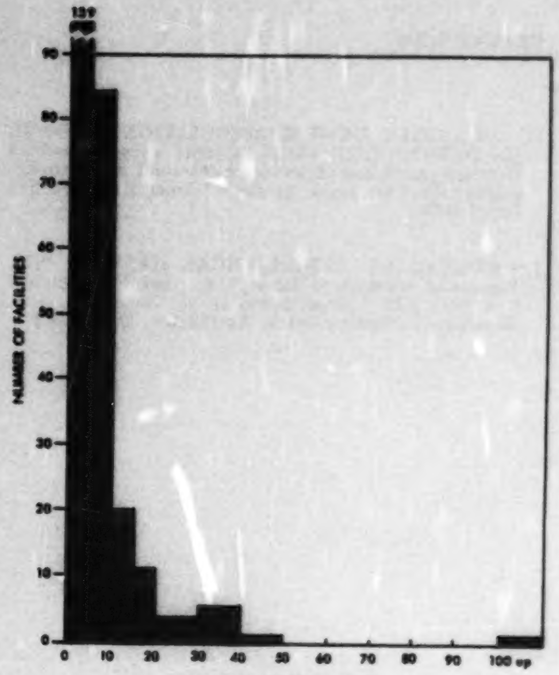

Figure 1. Distribution of priority numbers for dentists

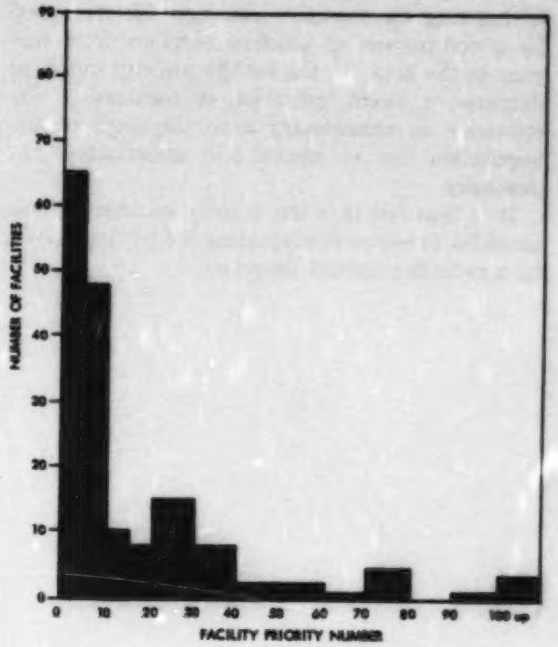

Figure 2. Distribution of priority numbers for physicians

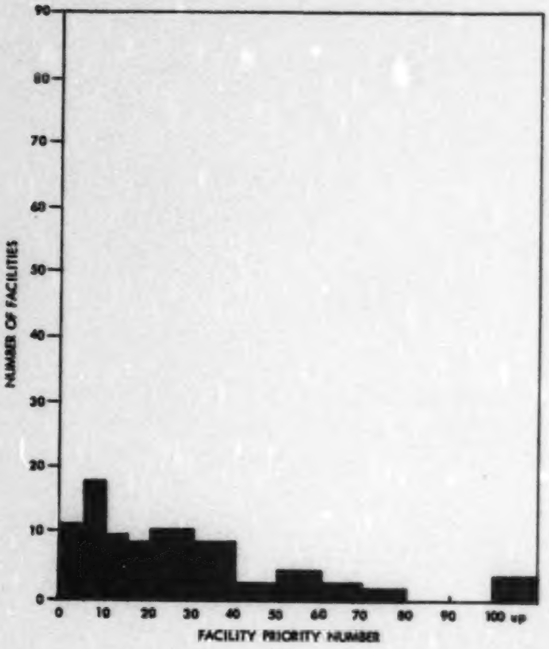

Figure 3. Distribution of priority numbers for hospitals

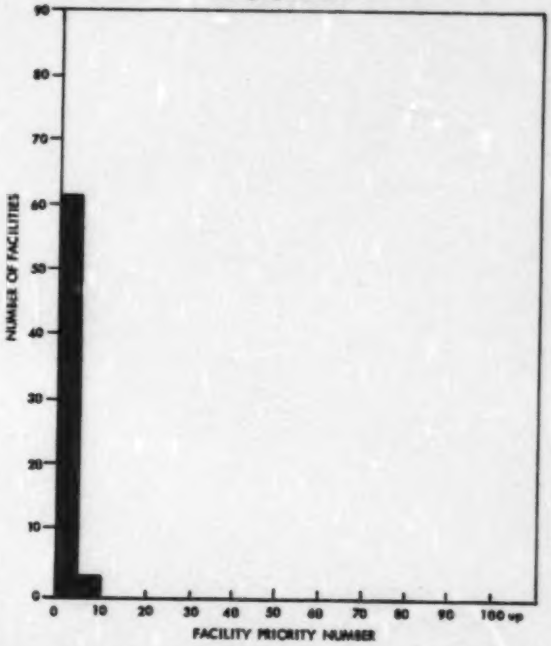

Figure 4. Distribution of priority numbers for chiropractors

The success and effectiveness of the program in meeting its objective can now be measured by a comparison of priority numbers from one year to the next. As the facility priority numbers decrease, a direct indication or measure of the reduction in unnecessary x-ray exposure to the population can be shown and quantitated numerically.

It is thus felt that the priority number system provides a method of evaluating the service offered by a radiation control program.

REFERENCES

(*1*) AMERICAN DENTAL ASSOCIATION COUNCIL ON DENTAL RESEARCH. Council adopts American standard speed classification for intraoral dental radiographic film: diagnostic grade. J Amer Dent 230–233 (April 1968).

(*2*) BUREAU OF RADIOLOGICAL HEALTH, PHS. Population exposure to X-rays, U.S., 1964, PHS Publication No. 1519. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Disposal of Radioactive Wastes from U.S. Naval Nuclear-Powered Ships and Their Support Facilities, 1969

J. J. Mangeno and *M. E. Miles*[1]

This report summarizes data on disposal of radioactive wastes from U.S. Naval nuclear-powered ships and their support facilities and summarizes results of environmental monitoring performed to confirm adequacy of waste disposal limits and procedures. The waste disposal data presented show that the total long-lived radioactivity in liquid waste discharges associated with operation and maintenance of Naval nuclear-powered ships totaled 0.05 curies in 1969 for all harbors. This is comparable to the average of 0.2 curies discharged per year during the preceding 3 years for all harbors and is less than the average of 4 curies reported discharged per year during the preceding 5 years. Results of environmental surveys of harbor water and bottom sediment for gross radioactivity and for cobalt-60 have shown that (1) no increase in radioactivity above normal background levels has been detected in harbor water, (2) discharges of liquid wastes from U.S. Naval nuclear-powered ships have not caused a measurable increase in the general background radioactivity of the environment, and (3) low-level cobalt-60 radioactivity is detectable in localized areas of harbor bottom sediment around a few piers at operating bases and shipyards where maintenance and overhaul of Naval nuclear-powered ships have been conducted over a period of several years.

This report confirms that procedures used by the Navy to control discharges of radioactivity from U.S. Naval nuclear-powered ships and their support facilities are effective in protecting the health and safety of the general public.

The radioactivity in wastes discussed in this report originates in the pressurized water reactors of U.S. Naval nuclear-powered ships. As of the end of 1969, there were 87 nuclear-powered submarines and four nuclear-powered surface ships in operation. In these shipboard reactors, pressurized water circulating through the reactor core picks up the heat of nuclear reaction. Reactor cooling water circulates through a closed piping system including heat exchangers which transfer the heat to water in a separate secondary steam system; the steam is then used as the source of power for the propulsion plant as well as for auxiliary machinery. Discharges of radioactivity from ships occur primarily when reactor coolant water expands as a result of heating a reactor plant to operating temperature; this coolant passes through a purification system ion-exchange resin bed prior to discharge.

Construction, maintenance, overhaul and refueling of these nuclear propulsion plants involve various shipyards, submarine tenders, and submarine bases. Liquid wastes discharged at these support facilities result from operations such as draining shipboard reactor systems, decontaminating radioactivity contaminated piping systems, and laundering anti-contamination clothing worn by personnel. These facilities are equipped with processing systems to remove most of the radioactivity from liquid wastes prior to discharge into harbors. These facilities have continued to be improved to further reduce amounts of radioactivity discharged.

Discharge limits for the low-level radioactive liquid wastes from U.S. Naval nuclear-powered ships and their support facilities are consistent with applicable recommendations issued by the Federal Radiation Council, U.S. Atomic Energy Commission (AEC), National Council on Radiation Protection and Measurements (NCRP), International Commission on Radiological Protection (ICRP), and National Academy of Sci-

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[1] Nuclear Power Directorate, Naval Ship Systems Command, Department of the Navy.

Table 1. Radioactive liquid waste discharges to harbors from U.S. Naval nuclear-powered ships and their support facilities for 1966 through 1969[a]

Facility	1966		1967		1968		1969	
	Thousand gallons	Curies	Thousand gallons	Curies	Thousand gallons	Curies	Thousand gallons	Curies
Portsmouth, N.H; Naval Shipyard	155	0.01	265	0.01	171	0.01		[b] ND
Quincy, Mass[c]; Quincy Division		ND		ND		ND		ND
Groton–New London, Conn; Electric Boat Division, State Pier, and submarine base	1,274	.03	606	.01	469	.01	615	.01
Newport News, Va; Newport News Shipbuilding	1,581	.06	1,533	.04	1,146	.03	870	.02
Norfolk, Va; Naval Shipyard and base	1,051	.03	1,784	.03		ND		ND
Charleston, S.C; Naval Shipyard and base	369	.04	320	.01		ND		ND
Pascagoula, Miss; Ingalls Shipbuilding Division		ND		ND		ND		ND
San Diego, Calif; Navy Pier at Ballast Point		ND		ND		ND		ND
Long Beach, Calif; Naval Shipyard and base		ND		ND		ND		ND
Vallejo, Calif; San Francisco Bay Naval Shipyard	270	.19		ND	391	.03		ND
Bremerton, Wash; Puget Sound Naval Shipyard		ND		ND		ND		ND
Pearl Harbor, Hawaii Naval Shipyard and base	654	.03	663	.01	886	.01	1,279	.01
Apra Harbor, Guam		ND		ND		ND		ND
All other harbors	178	.01		ND		ND		ND
Totals[d]	5,532	0.40	5,191	0.11	3,063	0.10	2,764	0.05

[a] Radioactivity data are recorded as if the entire radioactivity consisted of cobalt-60. Volumes are reported prior to dilution.

[b] Where discharges for a year totaled less than 0.005 curies, ND is reported.

[c] General Dynamics, Quincy Division, discharged a total of 0.02 curies into the river at Quincy, Mass., from 1961 through March 1969 when all work on U.S. Naval nuclear-powered ships was completed.

[d] Total curies for each year include discharges reported as ND.

ences—National Research Council (*1–5*). In consonance with these recommendations, the policy of the U.S. Navy is to minimize the amounts of radioactivity discharged into harbors. To implement this policy, the Navy has issued standard instructions defining the radioactive waste disposal limits and procedures to be used by U.S. Naval nuclear-powered ships and their support facilities. These instructions have been reviewed and concurred in by the U.S. Public Health Service and the U.S. Atomic Energy Commission.

The principal source of radioactivity in liquid wastes is from trace amounts of corrosion and wear products from reactor plant metal surfaces. The predominant long-lived radionuclide (i.e., half-life greater than one day) in these corrosion and wear products is cobalt–60, which has a 5.3 year half-life; cobalt–60 also has the lowest concentration guide for water (*2–4*) for these corrosion and wear radionuclides. Therefore, radioactive waste disposal is controlled by assuming that all the long-lived radioactivity is cobalt–60. Short-lived radionuclides decay rapidly and are therefore less limiting than long-lived radioactivity for waste disposal considerations.

Fission products produced in the reactor are retained by being metallurgically bound within the fuel alloy. The fission gases, krypton and xenon, are also retained within the fuel elements. As a result, the total radioactivity attributed to long-lived fission products (strontium–90 and cesium–137) in discharges from U.S. Naval nuclear-powered ships and their support facilities has been less than one millicurie per year for all harbors combined.

Small amounts of tritium are formed in reactor coolant systems as a result of neutron interaction with the approximately 0.01 percent of deuterium normally present in water, and other nuclear reactions. Although tritium has a 12-year half-life, the radiation produced is of such low energy that the radioactivity concentration limit used for tritium is 100 times that for cobalt–60. This tritium is in the oxide form and therefore completely soluble in water; it does not concentrate in marine life or collect on sediment since it is chemically indistinguishable from water. The small amounts of tritium from Naval reactors are rapidly diluted to the concentrations already existing in the environment. Since tritium from Naval reactors is not significant for waste disposal considerations in harbors, it is not included with other long-lived radionuclides in this report.

The total amounts of long-lived radioactivity discharged into various harbors during the past four years are listed in table 1, which updates information in references 6, 7, 8, and 9; included are data from U.S. Naval nuclear-powered ships and from supporting shipyards, tenders, and submarine bases. Locations listed in table 1 include operating bases and home ports in the United States and possessions which have been regularly visited by Naval nuclear-powered ships. The quantities of radioactivity listed in this

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table are reported as if the entire radioactivity consisted of cobalt-60, the predominant long-lived radionuclide.

The table shows that nearly all the radioactive discharges occur where shipyards are overhauling nuclear-powered ships. In 1969, for example, a total of 0.05 curies was discharged into all harbors, including those outside the United States. Essentially all of this came from shipyards overhauling nuclear-powered ships. Less than one percent of the total was discharged into all other harbors entered by U.S. Naval nuclear-powered ships in 1969. The low amounts of radioactivity in table 1 discharged by each facility are comparable to amounts discharged into rivers by a number of other facilities in the United States involved in nuclear power programs where stringent waste disposal controls similar to those used by the Navy are enforced.

During maintenance and overhaul operations, solid low-level radioactive wastes consisting of contaminated rags, plastic bags, paper and scrap materials are collected by nuclear-powered ships and their support facilities. Disposal of these wastes at sea is prohibited by the U.S. Navy. Solid materials from ships are transferred to a shipyard or other support facilities for packaging and disposal. In a similar fashion, shipyards and other support facilities also package for disposal solid waste, such as filters and ion-exchange resin resulting from liquid waste processing operations. For ultimate disposal, solid radioactive wastes are shipped to AEC-approved burial sites since shipyards and shore facilities are not permitted to dispose of radioactive solid wastes by burial on their own sites. Table 2 summarizes total radioactivity and volumes of radioactive wastes disposed of from 1966 through 1969.

Table 2. Radioactive solid waste disposed of by facilities supporting U.S. Naval nuclear-powered ships for 1966 through 1969[a]

Facility	1966		1967		1968		1969	
	Hundred cubic feet	Curies	Hundred cubic feet	Curies	Hundred cubic feet	Curies	Hundred cubic feet	Curies
Portsmouth, N.H; Naval Shipyard	194	9.5	300	198.1	314	150.7	77	3.1
Quincy, Mass; Electric Boat Division		[b] ND		ND		ND		ND
Groton, New London, Conn; Electric Boat Div. tender at State Pier, and submarine base	148	1,092.8	46	17.0	44	20.7	83	327.6
Newport News, Va; Newport News Shipbuilding	70	8.9	167	701.9	144	10.2	170	382.3
Norfolk, Va; Naval Shipyard and tender	43	2.5	108	85.6	23	11.2	63	8.4
Charleston, S.C; Naval Shipyard and tender	77	5.6	151	52.0	136	109.9	149	9.1
Pascagoula, Miss; Ingalls Shipbuilding Division		ND		ND		ND		ND
San Diego, Calif; tenders at Ballast Point	6	.1	7	.2	14	7.6	4	2.1
Long Beach, Calif; Naval Shipyard and base		ND		ND		ND		ND
Vallejo, Calif; San Francisco Bay Naval Shipyard	90	367.0	92	22.8	76	6.6	78	4.8
Bremerton, Wash; Puget Sound Naval Shipyard	14	.5	141	192.8	139	48.2	106	41.6
Pearl Harbor, Hawaii; Naval Shipyard and base	7	.3	11	1.0	32	5.5	41	3.3
Total	649	1,487.2	1,023	1,271.4	922	370.6	771	782.3

[a] Where total radioactivity is less than 0.5 curies, ND is reported in this table.
[b] This table includes waste from tenders and nuclear-powered ships since all such waste is transferred to the above support facilities.

Environmental monitoring

Environmental monitoring surveys for radioactivity are periodically performed in harbors where U.S. Naval nuclear-powered ships are built or overhauled and where these ships have home ports or operating bases. These surveys are performed to verify the adequacy of liquid waste disposal procedures and limits.

Shipyards, tenders, and submarine bases have taken periodic samples of harbor water and bottom sediment in the vicinity of berths used by nuclear-powered ships, beginning in each harbor prior to operation of these ships. Radioactivity data from harbor water and sediment samples taken by individual facilities indicate that operation and maintenance of nuclear-powered ships have not caused significant changes in the gross radioactivity of harbor water or sediment. However, relatively large variations in gross radioactivity measured in environmental samples do occur from changes in natural and fallout sources. Because of these variations, monitoring for gross radioactivity in harbor water and sediment is not sufficient to detect small changes in environ-

Table 3. Summary of 1969 surveys for cobalt-60 in bottom sediment of U.S. harbors where U.S. Naval nuclear-powered ships have been regularly based, overhauled or built

Facility	Number of samples with concentration[a] of cobalt-60:			Total bottom area with cobalt-60 over 10 pCi/cm^2 (km^2)	Estimated total cobalt-60 in top layer of sediment[b] (Ci)
	<10 pCi/cm^2[a]	10-100 pCi/cm^2[a]	>100 pCi/cm^2[a]		
Portsmouth, N.H. Naval Shipyard	176	0	0	0	ND
Quincy, Mass; Quincy Division (final survey)	24	0	0	0	ND
Groton-New London, Conn; Electric Boat Division, State Pier, and submarine base	322	130	2	0.1	0.02
Newport News, Va; Newport News Shipbuilding	151	1	0	.001	ND
Norfolk, Va; Naval Shipyard and base	344	0	0	0	ND
Charleston, S.C; Naval Shipyard and base	372	1	0	.001	ND
Pascagoula, Miss; Ingalls Shipbuilding Division	174	0	0	0	ND
San Diego, Calif; Navy Pier at Ballast Point	159	1	0	.001	ND
Long Beach, Calif; Naval Shipyard and base	160	0	0	0	ND
Vallejo, Calif; San Francisco Bay Naval Shipyard	444	0	0	0	ND
Bremerton, Wash; Puget Sound Naval Shipyard	138	0	0	0	ND
Pearl Harbor, Hawaii Naval Shipyard and base	261	7	0	.05	ND
Apra Harbor, Guam	123	0	1	0	

[a] Minimum detectable radioactivity is approximately 2 pCi/cm^2. Results in units of pCi/gram are approximately half the value in pCi/cm^2.

[b] Total is from areas with cobalt-60 over 10 pCi/cm^2, which were in immediate vicinity of piers used for berthing nuclear-powered ships. Where total cobalt-60 is less than 0.01 curie, ND is reported. Core samples more than 1 foot deep from several harbors show that total cobalt-60 present may be two to five times that measured in the surface layer.

mental radioactivity which might be attributed to operation and maintenance of naval nuclear-powered ships.

To monitor for these small changes in environmental radioactivity, water and sediment samples are analyzed specifically for cobalt-60. This radionuclide is a sensitive tracer to follow environmental distribution of radioactivity because it has the longest half-life and is the predominant long-lived radionuclide in liquid waste discharges; in addition, cobalt-60 concentrations from fallout are less than the minimum detectable with the sensitive monitoring equipment available at support facilities.

Once each quarter year a total of at least five water samples is taken at various locations in each harbor in areas where nuclear-powered ships berth and from upstream and downstream locations. These samples are analyzed for gross radioactivity and for cobalt-60, using a sodium iodide scintillation detector with a multichannel analyzer. No increases in gross radioactivity of harbor water have been detected. No harbor water samples have shown detectable cobalt-60 radioactivity; the minimum level detectable with the equipment and procedures used is 100 pCi/liter. The concentration of cobalt-60 in this water would have to be 300 times greater than 100 pCi/liter to reach maximum levels permitted by agencies such as the U.S. Atomic Energy Commission and International Commission on Radiological Protection.

Monitoring for cobalt-60 in harbor bottom sediment is conducted each quarter year by collecting 20 to 100 samples with a 6-inch-square sampler. Equipment and procedures for analyzing sediment samples are the same as for water samples discussed above. Samples are taken of the top 1/2 to 1 inch of sediment in the immediate vicinity of and away from berthing areas used by Naval nuclear-powered ships. Results of the 1969 surveys, which involved a total of 3,637 samples, are summarized in table 3. Low-level cobalt-60 radioactivity in harbor bottom sediment is detectable around a few piers at operating bases and shipyards where nuclear-powered ship maintenance and overhauls have been conducted over a period of several years. Cobalt-60 is not detectable above background levels in general harbor bottom areas away from these piers.

Samples from each of these harbors are also checked at least annually by an AEC laboratory to ensure analytical procedures are correct and standardized. In addition, the U.S. Navy cooperates in U.S. Public Health Service (PHS) surveys in some U.S. harbors. Results reported in table 3 are consistent with these AEC and PHS checks.

Twice per year shoreline areas uncovered at low tide are surveyed for radiation levels with sensitive radiation detectors to determine if any radioactivity from bottom sediment washed ashore. All results were 0.01 to 0.04 millirem per hour, the same as background radiation levels in

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similar areas. Thus there is no evidence in these ports that radioactivity from sediment is washing ashore.

Throughout the year, film badges are posted at locations outside the boundaries of areas where work with radioactivity is performed. These films showed that radiation exposure to the general public outside these facilities was not above that received from natural background radiation levels.

All exhaust stacks at support facilities which could have discharged airborne radioactivity were monitored. There were no discharges of airborne radioactivity to the atmosphere measured above concentrations normally present in the atmosphere.

In addition to the locations listed in table 3, environmental monitoring has been accomplished by U.S. Navy submarine tenders which serve as operating bases for U.S. Naval nuclear-powered submarines in Rota, Spain, and Holy Loch, Scotland. Results of the surveys in the harbor at Rota, Spain, have not shown detectable cobalt-60 in harbor sediment samples. In 1965, in Holy Loch, more cobalt-60 radioactivity than expected was detected in harbor bottom sediment and on shore line mud flat areas uncovered at low tide. However, there had been no increase of harbor water radioactivity in Holy Loch above normal background levels. Joint U.S. and British assessments of survey results confirmed that radiation levels in the vicinity of the Holy Loch anchorage were far below those which were at all likely to cause an individual to receive radiation exposure approaching limits for members of the general public. Environmental monitoring during 1969 showed radioactivity levels in Holy Loch are steadily declining.

Summary

Overall results of environmental surveys performed in 1969 indicate the following:

(1) No increase of radioactivity above normal background levels has been detected in harbor water where U.S. Naval nuclear-powered ships are based, overhauled, or constructed.

(2) Discharges of liquid wastes from U.S. Naval nuclear-powered ships have not caused a measurable increase in the general background radioactivity of the environment.

(3) Low-level cobalt-60 radioactivity in harbor bottom sediment is detectable around a few piers at operating bases and shipyards where nuclear-powered ship maintenance and overhauls have been conducted over a period of several years. Cobalt-60 is not detectable above background levels in general harbor bottom areas away from these piers. Maximum total radioactivity observed in a U.S. harbor is less than one curie of cobalt-60.

REFERENCES

(*1*) Federal Radiation Council Memoranda, approved by President Eisenhower on May 13, 1960, President Kennedy on September 20, 1961, and President Johnson on July 31, 1964.

(*2*) Code of Federal Regulations, Title 10 (Atomic Energy Commission) Part 20, Standards for Protection Against Radiation.

(*3*) NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS. Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure, Report No. 22. NBS Handbook 69 (June 1959).

(*4*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendations of the International Commission on Radiological Protection, Report of Committee II on permissible dose for internal radiation (1959); 1962 Supplement in ICRP Publication 6; Recommendations on Radiation Exposure, ICRP Publication 9 (1965); and ICRP Publication 7 (1965).

(*5*) NATIONAL ACADEMY OF SCIENCES. Radioactive Waste Disposal from Nuclear-Powered Ships, Publication 658, National Research Council, Washington, D.C. (1959).

(*6*) VAUGHAN, J. W. and M. E. MILES. Disposal of radioactive wastes from U.S. Naval nuclear-powered ships and their support facilities, 1965. Radiol Health Data Rep 7:257–262 (May 1966).

(*7*) MILES, M. E. and J. J. MANGENO. Disposal of radioactive wastes from U.S. Naval nuclear-powered ships and their support facilities, 1966. Radiol Health Data Rep 8:699–701 (December 1967).

(*8*) MILES, M. E. and J. J. MANGENO. Disposal of radioactive wastes from U.S. Naval nuclear-powered ships and their support facilities, 1967. Radiol Health Data Rep 10:135–138 (April 1969).

(*9*) MILES, M. E. and J. J. MANGENO. Disposal of radioactive wastes from U.S. Naval nuclear-powered ships and their support facilities, 1968. Radiol Health Data Rep 10:375–377 (September 1969).

Standby Milk Surveillance Network

Thomas J. Sharpe and *John L. Stein*[1]

The operation of the Standby Milk Surveillance Network of the Southwestern Radiological Health Laboratory is described. Portions of the network have been activated on several occasions. Fresh fission products have been defined in a number of samples collected from processing plants in the network, although in all cases the concentrations of the radionuclides present have been well below the recommendations of the Federal Radiation Council.

Since 1954, the Public Health Service (PHS), under terms of A Memorandum of Understanding, SF54-373, negotiated between the PHS and the Atomic Energy Commission (AEC), has been charged with the responsibility of providing a radiological safety program beyond the boundaries of the AEC's Nevada Test Site (NTS). Prior to this time, a combination of military and AEC laboratory personnel had provided radiological safety services for the test series conducted. An offsite Radiological Safety Organization (which later evolved into the Southwestern Radiological Health Laboratory (SWRHL), was established in Las Vegas, Nev., to direct and coordinate the various activities of radiation monitoring and environmental surveillance needed to implement the program. In addition to monitoring radioactivity released by individual nuclear tests, SWRHL operates a number of surveillance networks for the AEC on a continuous basis to document any increase in radiation levels due to nuclear testing programs. These networks sample milk, water, and air in the offsite areas and provide more specific information regarding changes in the radiological situation than does radiation monitoring.

Purpose and scope

The value of milk as a sensitive indicator of atmospheric radiocontaminant intake by the general population has been well documented. Extensive reliance on milk sampling for information on current levels and long-range trends of specific contaminants is based upon several facts. Milk is one of the most universally consumed foodstuffs. It reflects several important nuclides (strontium-90, iodine-131, cesium-137) deposited in the area from which it is collected, and it is one of the most convenient dietary constituents to collect, handle, and analyze.

Prior to the establishment of the Standby Milk Surveillance Network (SMSN), other milk sampling networks had been set up by SWRHL and by Headquarters, Bureau of Radiological Health (BRH). The Routine Milk Surveillance Network (RMSN) was set up by SWRHL in 1959 to provide concentrated surveillance in an area limited to within 300 miles of NTS. The Pasteurized Milk Network (PMN), operated by BRH, covers the entire United States and has the objective of providing data on current radionuclide concentrations and long-term trends. Prior to the creation of the SMSN, it was recognized that occasions might arise when concentrated surveillance of milksheds would be needed in areas outside those covered by the RMSN. It was also recognized the limited number of stations in the PMN could not properly reflect the intrusion of radioactive contaminants into all the milksheds possibly affected by a release of radioactivity from a nuclear device or reactor test at NTS. Therefore, the SMSN was created in 1964 to provide ad-

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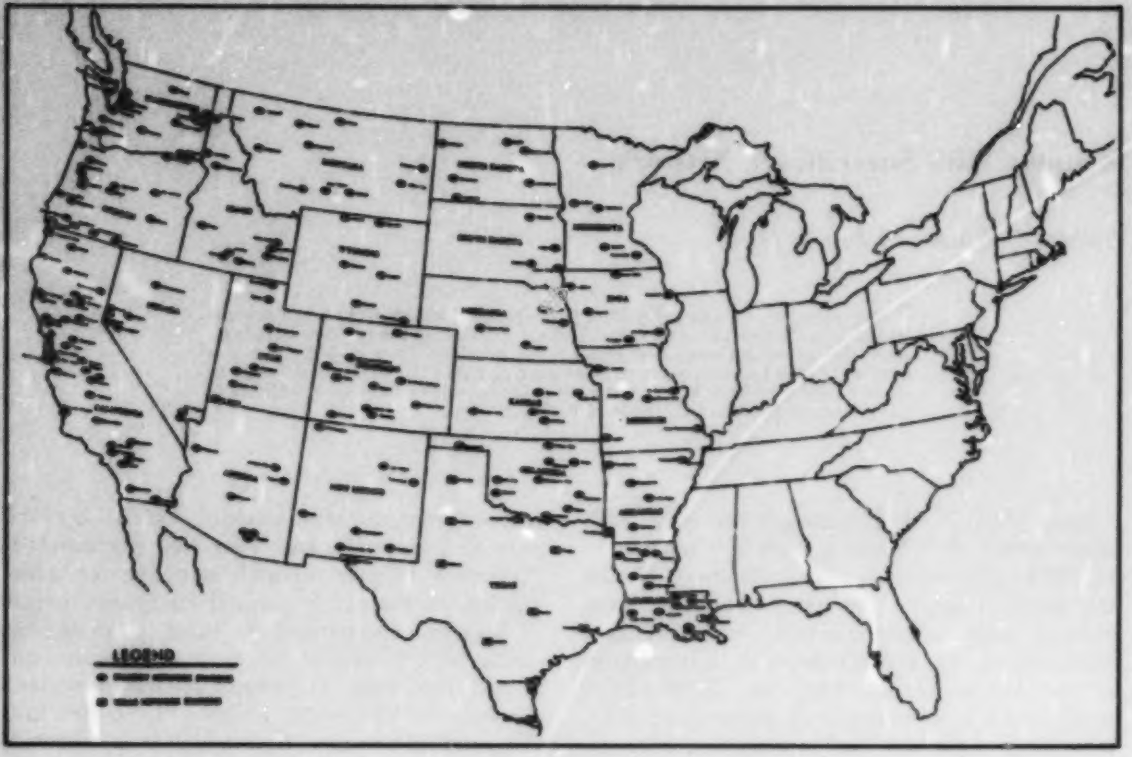

Figure 1. Standby milk surveillance stations

ditional surveillance capability. This new network differed from those established previously in that it was not designed to operate on a continuous basis. It was decided that the SMSN could be activated after a release had occurred and the direction in which the radioactive material was moving had been defined, thereby keeping the number of samples to a minimum without limiting the effectiveness of the network.

Organization

Originally, the network consisted of 161 milk processing plants in the eleven western-most States. The State of Texas was also included to the extent that either samples or analytical results from this State's milk sampling network would be made available to SWRHL upon request. In 1969, the remainder of the States west of the Mississippi River were added to the network, bringing the total number of milk processing plants in the network to 201. The current network is shown in figure 1.

The network stations were established through the cooperation and participation of personnel from the Bureau of Radiological Health, Environmental Health Service, and the Bureau of Food and Pesticides, Food and Drug Administration, (formerly, Division of Radiological Health and Division of Environmental Engineering and Food Protection), and State and local milk control agencies.

The milk processing plants in the network were selected to provide a geographical distribution such that any contamination detected could be traced to a specific milkshed. The management of each selected processing plant was then asked to participate in the program by supplying samples for radionuclide analysis and providing basic information for evaluation and reporting purposes.

Network activation

To activate any part of the network, the project officer at SWRHL contacts the appropriate PHS regional office. This office is then responsible for contacting the State milk control officials concerned; they, in turn, notify local milk control personnel (city or county) who begin collecting and airmailing samples to SWRHL for analysis. The regional offices notify the Chief, Milk Sanitation Section, Food and Drug Administration, and SWRHL notifies the Chief, Radiological Surveillance Branch, Bureau of Radiological Health, once the activation procedure has begun.

Except for periodic 1-day trial runs to determine the readiness of the network, sampling at the stations activated is normally carried on for a 1-week period. This may be extended when deemed necessary. All agencies involved in the sample collection effort have been instructed to provide raw milk samples. This policy has been instituted for several reasons. For example, some processors receive raw milk from numerous, widely-scattered milksheds. Sampling of the pasteurized milk could possibly mask significant amounts of contaminants in the milk coming from a portion of the milksheds supplying a particular plant. The time between milking and analysis is also reduced by sampling raw milk. This factor is important since the majority of the radionuclides which may be injected into the environment by nuclear testing possess half-lives in terms of hours and days.

Sample analysis and reporting

Upon receipt, samples are analyzed by gamma spectroscopy for iodine-131, cesium-137, barium-140, and other radionuclides. The first sample received from each station and all subsequent

Table 1. Summary of operation of the Standby Milk Surveillance Network[a]

Nuclear event	State notified	Date of activation	Stations activated	Stations positive for iodine-131	Samples collected	Samples positive for iodine-131
Kiwi-TNT[b]	California	1/12/65	8	0	55	0
Palanquin[c]	Idaho	4/16/65	11	3	175	29
	Montana	4/17/65	13	7	175	15
	Oregon	4/16/65	5	1	28	1
	Utah	4/17/65	5	0	32	0
	Washington	4/17/65	10	0	54	0
	Wyoming	4/17/65	6	0	37	0
Pin Stripe[d]	California	4/25/66	7	0	27	0
	Colorado	4/25/66	13	0	64	0
	Idaho	4/25/66	11	1	40	2
	Utah	4/25/66	9	1	45	2
	Wyoming	4/25/66	6	0	41	0
NRX-A5[b]	Utah	6/29/66	4	0	17	0
Phoebus 1B EP-4[b]	California	2/23/67	5	0	34	0
	Idaho	2/23/67	11	1	70	1
	Montana	2/23/67	5	0	35	0
	Utah	2/23/67	8	1	40	1
	Wyoming	2/23/67	5	0	23	0
Non U.S. test	California	6/22/67	8	0	46	0
Umber[d]	California	6/29/67	11	0	37	0
NRX-A6[b]	California	12/18/67	11	0	40	0
Hupmobile[d] Cabriolet[c]	California	1/19/68	5	0	25	0
	Idaho	1/28/68	9	0	40	0
	Montana	1/26/68	7	0	41	0
Buggy I[c]	Idaho	3/12/68	6	0	32	0
	Montana	3/12/68	4	0	30	0
	Utah	3/12/68	3	0	18	0
	Wyoming	3/12/68	3	0	13	0
Schooner[c]	Colorado	12/10/68	11	0	60	0
	Idaho	12/10/68	7	0	34	0
	Montana	12/10/68	6	0	19	0
	Utah	12/10/68	8	0	45	0
	Wyoming	12/10/68	6	0	23	0

[a] The network was not activated in 1969.
[b] Nuclear reactor experiment.
[c] Plowshare experiment.
[d] Weapon test.

samples found to contain fresh fission products receive radiochemical analysis for strontium-89 and strontium-90. If the iodine-131 concentration in any sample should exceed 100 pCi/liter, regional FDA milk and food consultants would be contacted. These personnel would then notify State public health authorities in their region and alert them to the increased levels of iodine-131.

Analytical results of all samples are reviewed, evaluated, and tabulated by SWRHL. The data are then sent to the PHS regional milk consultants concerned for distribution to the state authorities in their region.

Operational experience

Portions of the network have been activated on several occasions. Fresh fission products have been detected in a number of samples collected from processing plants in the network, although in all cases, the concentrations of the radionuclides present have been well below the standards prescribed by the Federal Radiation Council (*1*). A summary of the operation of the Standby Milk Surveillance Network is presented in table 1.

Summary

The practicality of the "standby" concept of milk surveillance has been proven through the operation of the SMSN. Experience has shown that after initial notification samples can be received and counted in as little as 1 day's time, although 2 to 3 days are usually required. By maintaining communication with local control authorities and by staging periodic trial runs, an excellent degree of readiness has been maintained in the system.

REFERENCE

(*1*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

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Data

SECTION I. MILK AND FOOD

Milk Surveillance, April 1970

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radioactive contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation and/or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Bureau of Radiological Health and the Bureau of Foods, Pesticides and Product Safety, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Public Health Service)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements, calcium and potassium, which are found in milk have been used as a means for assessing the biological behavior of metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of

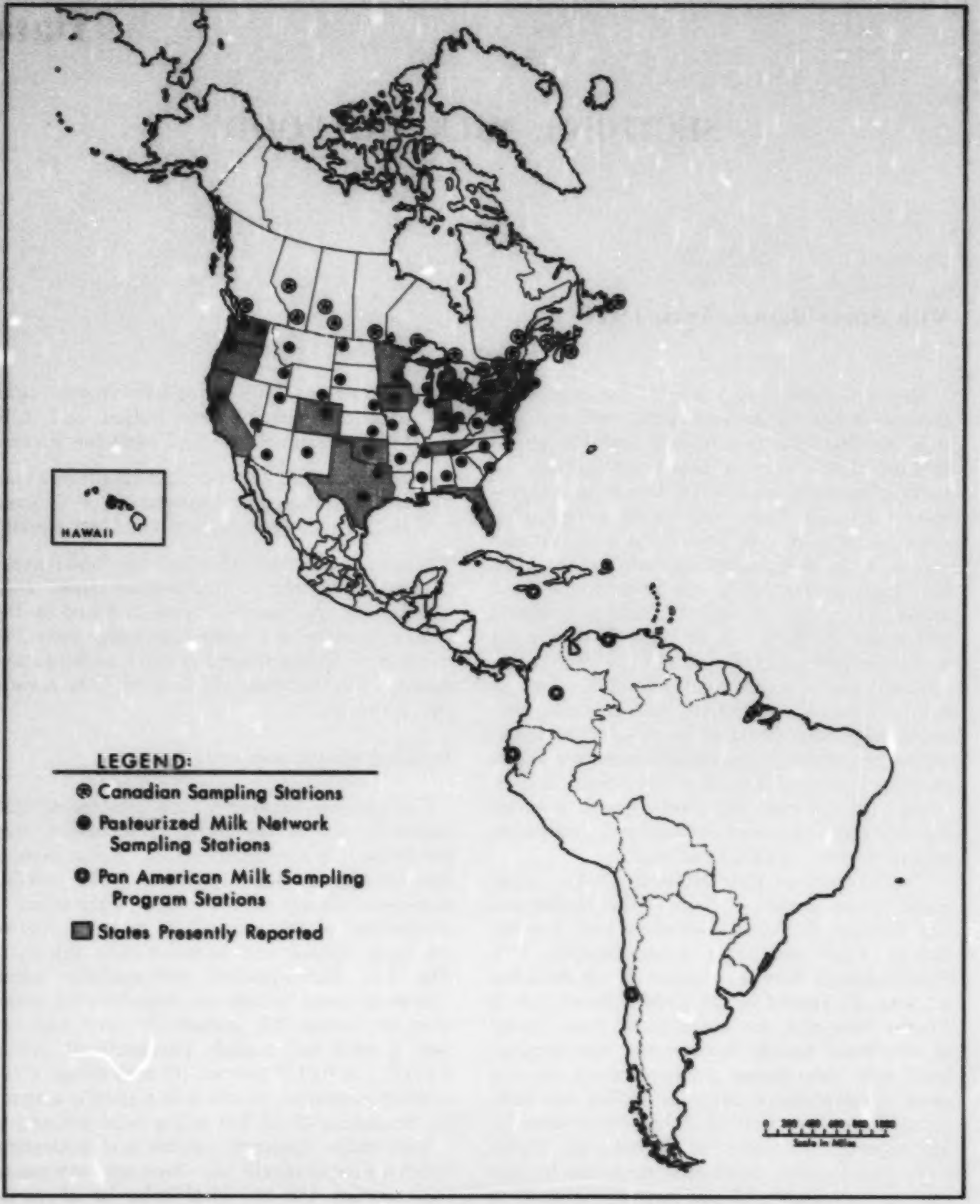
HAWAII
LEGEND:
⊛ Canadian Sampling Stations
● Pasteurized Milk Network Sampling Stations
○ Pan American Milk Sampling Program Stations
▨ States Presently Reported
0 200 400 600 800 1000
Scale in Miles

Figure 1. Milk sampling networks in the Western Hemisphere

both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2-standard deviations, for these concentrations are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Bureau of Radiological Health conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested public health radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted in the period, July–September 1969, with 31 laboratories participating in an experiment on milk samples containing known concentrations of strontium–89, strontium–90, iodine–131, cesium–137 and barium–140. Of the 18 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 14 participated in the experiment.

The iodine–13[illegible] and cesium–137 results show much improvement over previous tests. Barium–140 results also look good which is encouraging, since this is the first time barium–140 was analyzed for this type of experiment. However, strontium–89 and strontium–90 analyses still need improvement (*5*). Keeping these possible differences in mind, integration of the data from the various networks can be undertaken without introducing a serious error due to disagreement among the independently obtained data.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium–40, iodine–131, cesium–137, and barium–140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports*.

A recent article (*6*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and earlier data articles for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. The frequency of collection and analysis varies not only among the networks, but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium–90 and cesium–137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine–131, the frequency of analysis is critical, and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data presentation also reflects whether raw or pasteurized milk was collected. A recent analysis (*7*) of raw and pasteurized milk samples collected during the period, January 1964 to June 1966, indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant. Particular attention was paid to strontium–90 and cesium–137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard deviation counting errors or 2-standard deviation total analytical errors from replicate analyses experiments (*3*). The practical reporting level reflects additional analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium–89	5
Strontium–90	2
Iodine–131	10
Cesium–137	10
Barium–140	10

Some of the networks gave practical reporting levels greater than those above. In these cases the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error or precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium–89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter;
Strontium–90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter
Iodine–131 Cesium–137 Barium–140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥100 pCi/liter

For iodine–131, cesium–137, and barium–140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions is presented below. The function of the Council is to provide guidance to Federal agencies in the formulation of radiation standards.

Radiation Protection Guides (*8, 9*)

The Radiation Protection Guide (RPG) has been defined by the Federal Radiation Council (FRC) as the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable. An RPG provides radiation protection guidance for the control and regulation of normal peacetime uses of nuclear technology in which control is exercised primarily at the source through the design and use of nuclear material. It represents a balance between the possible risk to the general public that might result due to exposures from routine uses of ionizing radiation and the benefits from the activities causing the exposure.

Table 1 presents a summary of guidelines and related information on environmental radiation levels as set forth by the FRC for the conditions under which RPG's are applicable. A more detailed discussion of these values was presented earlier (*3*).

In the absence of specific dietary data, one can use milk as the indicator food item for routine surveillance. Assuming a 1-liter per day intake of milk, one can utilize the graded approach of daily intake on the basis of radionuclide content in milk samples collected to represent general population consumption. Under these assumptions, the radionuclide concentrations in pCi/liter of milk can replace the daily radionuclide intake in pCi/day in the three graded ranges.

Table 1. Radiation Protection Guides—FRC recommendations and related information pertaining to environmental levels during normal peacetime operation

Nuclide	Critical organ	RPG for individual in the general population (rad/a)	Guidance for suitable samples of exposed population group[a]				
			RPG (rad/a)	Corresponding continuous daily intake (pCi/day)	Range I[b] (pCi/day)	Range II[b] (pCi/day)	Range III[b] (pCi/day)
Strontium-89	Bone	[c]1.5	0.5	[d]2,000	0-200	200-2,000	2,000-20,000
	Bone marrow	[c] .5	.17				
Strontium-90	Bone	[c]1.5	.5	[d]200	0-20	20-200	200-2,000
	Bone marrow	[c] .5	.17				
Iodine-131	Thyroid	1.5	.5	100	0-10	10-100	100-1,000
Cesium-137[e]	Whole body	.5	.17	3,600	0-360	360-3,600	3,600-36,000

[a] Suitable samples which represent the limiting conditions for this guidance are: strontium-89, strontium-90—general population; iodine-131—children 1 year of age; cesium-137—infants.

[b] Based on an average intake of 1 liter of milk per day.

[c] A dose of 1.5 rad/a to the bone is estimated to result in a dose of 0.5 rad/a to the bone marrow.

[d] For strontium-89 and strontium-90, the Council's study indicated that there is currently no operational requirement for an intake value as high as one corresponding to the RPG. Therefore, these intake values correspond to doses to the critical organ not greater than one-third the respective RPG.

[e] The guides expressed here were not given in the FRC reports, but were calculated using appropriate FRC recommendations.

Protective Action Guides (*10, 11*)

The Protective Action Guide (PAG) has been defined by the Council as the projected absorbed dose to individuals in the general population that warrants protective action following a contaminating event. A PAG provides general guidance for the protection of the population against exposure by ingestion of contaminated foods resulting from the accidental release or the unforeseen dispersal of radioactive materials in the environment. A PAG is also based on the assumption that such an occurrence is an unlikely event, and circumstances that might involve the probability of repetitive occurrences during a one or two year period in a particular area would require special consideration. Protective actions are appropriate when the health benefits associated with the reduction in exposure to be achieved are sufficient to offset the undesirable features of the protective actions.

Table 2 presents a summary of guidelines as set forth by the FRC for the conditions under which PAG's are applicable. A more detailed discussion of these values was presented earlier (*3*). Also given in table 2 are milk concentrations for each of the radionuclides considered, in the absence of others, which, if attained after an acute incident, would result in doses equivalent to the appropriate PAG. These concentrations are based on a projection of the maximum concentration from an idealized model for any acute deposition and the pasture-cow-milk-man pathway, as well as an estimate of the intake prior

Table 2. Protective Action Guides—FRC recommendations and related information pertaining to environmental levels during an acute contaminating event

Radionuclide	Critical organ	PAG for individuals in general population (rads)	Category (pasture-cow-milk)	
			Guidance for suitable sample, children 1 year of age	
			PAG (rads)	Maximum concentration in milk for single nuclide that would result in PAG (pCi/liter)
Strontium-89	Bone marrow	10 in first yr; total dose not to exceed 15[a,b]	3 in first yr; total dose not to exceed 5[a,b]	[c]1,110,000
Strontium-90	Bone marrow			[c]51,000
Cesium-137	Whole body			[c]720,000
Iodine-131	Thyroid	30	10	[d]70,000

[a] The sum of the projected doses of these three radionuclides to the bone marrow should be compared to the numerical value of the respective guide.

[b] Total dose from strontium-89 and cesium-137 is the same as dose in first year; total dose from strontium-90 is 5 times strontium-90 dose in first year for children approximately 1 year of age.

[c] These values represent concentrations that would result in doses to the bone marrow or whole body equal to the PAG, if only the single radionuclide were present.

[d] This concentration would result in the PAG dose based on intake before and after the date of maximum concentration observed in milk from an acute contaminating event. A maximum of 84,000 pCi/liter would result in a PAG dose if that portion of intake prior to the maximum concentration in milk is not considered. Children, 1 year of age, are assumed to be the critical segment of the population.

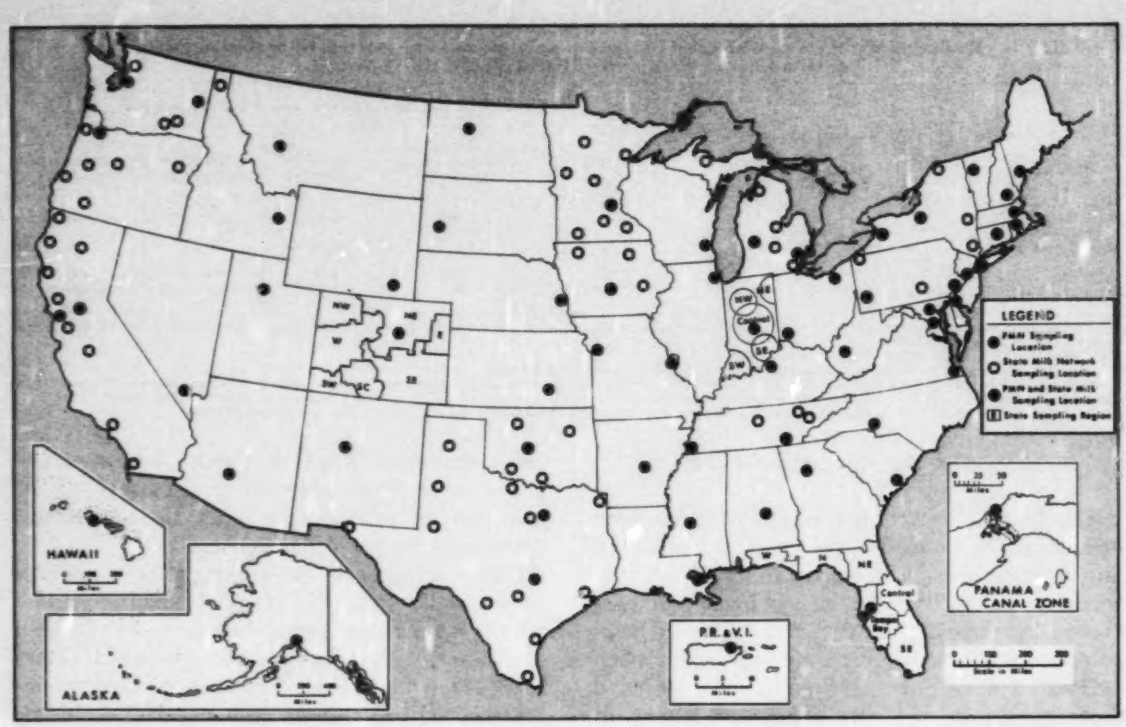

Figure 2. State and PMN milk sampling locations in the United States

to reaching the maximum concentration. Therefore, these maximum concentrations are intended for use in estimating future intake on the basis of a few early samples rather than in retrospective manner.

Data reporting format

Table 3 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports*. (The relationship between the PMN stations and State stations is shown in figure 2). The first column under each of the radionuclides reported gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 3, surveillance results are given for strontium-90, iodine-131 and cesium-137 for April 1970 and the 12-month period, May 1969 to April 1970. Except where noted the monthly average represents a single sample for the sampling station. Strontium-89 and barium-140 data have been omitted from table 3 since levels at the great majority of the stations for April 1970 were below

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Table 3. Concentrations of radionuclides in milk for April 1970 and 12-month period May 1969 through April 1970

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES:								
Ala:	Montgomery[c]	P	5	6	0 (5)	0	11 (5)	10
Alaska:	Palmer[c]	P	5	5	0 (4)	0	3 (4)	4
Ariz:	Phoenix[c]	P	2	1	0 (5)	0	0 (5)	0
Ark:	Little Rock[c]	P	9	14	0 (4)	0	19 (4)	18
Calif:	Sacramento[c]	P	5	2	0 (4)	0	0 (4)	0
	San Francisco[c]	P	6	2	0 (5)	0	0 (5)	0
	Del Norte	P	22	20	0	0	15	19
	Fresno	P	2	2	0	0	0	7
	Humboldt	P	7	5	0	0	0	6
	Los Angeles	P	2	2	0	0	0	3
	Mendocino	P	4	3	0	0	0	4
	Sacramento	P	3	3	0	0	0	4
	San Diego	P	2	2	0	0	0	2
	Santa Clara	P	2	2	0	0	0	4
	Shasta	P	3	3	0	0	0	5
	Sonoma	P	6	3	0	0	0	5
Colo:	Denver[c]	P	4	5	0 (5)	0	3 (5)	2
	West	P	(d)		(e) (6)	(e)	(e) (6)	(e)
	Northeast	R	(d)		(e) (2)	(e)	(e) (2)	(e)
	East	R	(d)		(e)	(e)	(e)	(e)
	Southeast	R	(d)		(e)	(e)	(e)	(e)
	South Central	R	(d)		NS	NS	NS	NS
	Southwest	R	(d)		(e) (2)	(e)	(e) (2)	(e)
	Northwest	R	(d)		(e)	(e)	(e)	(e)
Conn:	Hartford[c]	P	7	8	0 (4)	0	5 (4)	10
	Central	P	7	7	0 (4)	0	8 (4)	11
Del:	Wilmington[c]	P	7	8	0 (5)	0	6 (5)	5
D.C:	Washington[c]	P	8	7	0 (3)	0	3 (3)	5
Fla:	Tampa[c]	P	5	6	0 (4)	0	46 (5)	54
	West	R	7	11	0	0	11	21
	North	R	7	11	0	0	25	25
	Northeast	R	6	7	0	0	37	52
	Central	R	NA	8	0	0	40	43
	Tampa Bay area	R	6	7	0	0	46	54
	Southeast	R	8	8	0	0	39	79
Ga:	Atlanta[c]	P	12	9	0 (4)	0	18 (4)	18
Hawaii:	Honolulu[c]	P	0	2	0 (4)	0	0 (4)	0
Idaho:	Idaho Falls[c]	P	5	5	0 (4)	0	0 (4)	3
Ill:	Chicago[c]	P	6	7	0 (4)	0	5 (4)	8
Ind:	Indianapolis[c]	P	7	8	0 (4)	0	3 (4)	5
	Northeast	P	7	10	0	0	10	12
	Southeast	P	8	10	0	0	10	12
	Central	P	7	9	0	0	10	10
	Southwest	P	8	10	0	0	0	12
	Northwest	P	7	10	0	0	10	17
Iowa:	Des Moines[c]	P	7	6	0 (5)	0	0 (5)	2
	Iowa City	P	NS		NS		NS	
	Des Moines	P	NS		NS		NS	
	Spencer	P	NS		NS		NS	
	Fredericksburg	P	NS		NS		NS	
Kans:	Wichita[c]	P	8	8	0 (4)	0	0 (4)	0
Ky:	Louisville[c]	P	8	8	0 (4)	0	3 (4)	4
La:	New Orleans[c]	P	16	15	0 (4)	0	22 (4)	18
Maine:	Portland[c]	P	9	11	0 (5)	0	15 (5)	22
Md:	Baltimore[c]	P	5	8	0 (4)	0	3 (4)	6
Mass:	Boston[c]	P	8	10	0 (4)	0	18 (4)	20
Mich:	Detroit[c]	P	9	8	0 (5)	0	3 (4)	8
	Grand Rapids[c]	P	9	9	0 (4)	0	9 (4)	11
	Bay City	P	7	7	(e) (2)	(e)	19 (2)	9
	Charlevoix	P	NA	11	(e) (4)	(e)	15 (4)	18
	Detroit	P	5	6	(e) (4)	(e)	3 (4)	6
	Grand Rapids	P	9	8	(e) (4)	(e)	6 (4)	11
	Lansing	P	11	8	(e) (2)	(e)	13 (2)	15
	Marquette	P	NA	11	(e) (2)	(e)	23 (2)	25
	Monroe	P	NA	6	(e) (2)	(e)	0 (2)	2
	South Haven	P	NA	NA	(e) (4)	(e)	3 (4)	9
Minn:	Minneapolis[c]	P	8	10	0 (4)	0	2 (4)	6
	Bemidji	P	13	16	0	0	22	25
	Mankato	P	4	7	0	0	0	11
	Rochester	P	7	8	0	0	13	9
	Duluth	P	13	17	0	0	19	20
	Worthington	P	6	7	0	0	0	0
	Minneapolis	P	9	11	0	0	14	13
	Fergus Falls	P	6	9	0	0	0	0
	Little Falls	P	7	9	0	0	13	12
Miss:	Jackson[c]	P	13	12	0 (2)	0	8 (2)	12
Mo:	Kansas City[c]	P	9	8	0 (4)	0	0 (4)	1
	St. Louis[c]	P	6	8	0 (5)	0	3 (5)	2
Mont:	Helena[c]	P	4	5	0 (3)	0	5 (3)	5
Nebr:	Omaha[c]	P	4	6	0 (4)	0	0 (4)	1
Nev:	Las Vegas[c]	P	2	7	0 (4)	0	0 (4)	0

See footnotes at end of table.

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Table 3. Concentrations of radionuclides in milk for April 1970 and 12-month period May 1969 through April 1970—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA—Continued								
New Brunswick:	Fredericton	P	12	13	(d)		16	19
Newfoundland:	St. Johns	P	9	10	(d)		15	20
Nova Scotia:	Halifax	P	13	14	(d)		26	29
Ontario:	Ft. William	P	8	8	(d)		9	13
	Ottawa	P	16	14	(d)		30	29
	Saulte Ste. Marie	P	4	5	(d)		12	10
	Toronto	P	5	5	(d)		14	10
	Windsor	P	7	8	(d)		15	17
Quebec:	Montreal	P	8	11	(d)		23	26
	Quebec	P						
Saskatchewan:	Regina	P	6	7	(d)		15	12
	Saskatoon	P	9	8	(d)		9	11
CENTRAL AND SOUTH AMERICA:								
Columbia:	Bogota	P	2	2	0	0	0	0
Chile:	Santiago	P	0	0	0	0	0	2
Ecuador:	Guayaquil	P	0	0	0	0	0	0
Jamaica:	Kingston	P	8	5	0	0	30	94
Venezuela:	Caracas	P	2	2	0	0	0	0
Canal Zone:	Cristobal[c]	P	0	0	0 (4)	0	10 (4)	9
Puerto Rico:	San Juan[c]	P	4	3	0 (4)	0	4 (4)	7
PMN Network average [f]			7	7	0	0	6	8

[a] P, pasteurized milk. R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] PHS Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] Radionuclide analysis not routinely performed.

[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:

Iodine-131:	Cesium-137:	Strontium-90:
Colorado—25 pCi/liter	Colorado—25 pCi/liter	New York—3 pCi/liter
Michigan—14 pCi/liter	New York—20 pCi/liter	
Oregon—15 pCi/liter	Oregon—15 pCi/liter	

[f] This entry gives the average radionuclides concentrations for the PHS Pasteurized Milk Network stations denoted by footnote[c].

NA, no analysis.

NS, no sample collected.

the respective practical reporting levels. Averages for those stations at which strontium-89 was detected were Del Norte, Calif., 19 pCi/liter; and Humboldt, Calif., 6 pCi/liter.

Iodine-131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower values reflected by the radiation protection guidance provided by the Federal Radiation Council (table 1), levels in milk for this radionuclide are of particular public health interest. In general, the practical reporting level for iodine-131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Strontium-90 monthly averages ranged from 0 to 23 pCi/liter in the United States for the month of April 1970, and the highest 12-month average was 20 pCi/liter (Del Norte, Calif.) representing 10.0 percent of the Federal Radiation Council radiation protection guide (table 1). Cesium-137 monthly averages ranged from 0 to 46 pCi/liter in the United States for the month of April 1970, and the highest 12-month average was 79 pCi/liter (Southeast Fla.), representing 2.2 percent of the value presented in this report using the recommendation given in the Federal Radiation Council reports. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (*12*) and Jamaica. Iodine-131 results for individual samples were all below the practical reporting level.

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Radiological Health Section
Division of Air, Occupational and
Radiation Hygiene
Colorado State Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiological Health Service
Division of Occupational Health
Michigan Department of Health

Radiation Protection Division
Canadian Department of National
Health and Welfare

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Health
Division of Environmental Health Services
New York State Department of Health

Division of Occupational and Radiological
Health
Environmental Health Services
Oklahoma State Department of Health

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Office of Air Quality Control
Division of Technical Services
Washington State Department of Health

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REFERENCES

(1) CAMPBELL, J. E., G. K. MURTHY, A. S. GOLDIN, H. B. ROBINSON, C. P. STRAUB, F. J. WEBER and K. H. LEWIS. The occurrence of strontium–90, iodine–131, and other radionuclides in milk, May 1957 through April 1958. Amer J Public Health 49:225 (February 1959).

(2) Chart of the Nuclides, Ninth Edition revised to July 1966. Knolls Atomic Power Laboratory (November 1966).

(3) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Section I. Milk Surveillance. Radiol Health Data Rep 9:730–746 (December 1968).

(4) ROSENSTEIN, M. and A. S. GOLDIN. Statistical technics for quality control of environmental radioassay. Health Lab Sci 2:93 (April 1965).

(5) KNOWLES, F. Interlaboratory study of iodine–131, cesium–137, barium–140, strontium–89, and strontium–90 measurements in milk, July–September 1969. Technical experiment 69–MKAQ–2. Analytical Quality Control Service, Bureau of Radiological Health (October 1969).

(6) NEILL, R. H. and D. R. SNAVELY. State Health Department sampling criteria for surveillance of radioactivity in milk. Radiol Health Data Rep 8:621–627 (November 1967).

(7) ROBINSON, P. B. A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966. Radiol Health Data Rep 9:475–488 (September 1968).

(8) FEDERAL RADIATION COUNCIL. Background materials for the development of radiation protection standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 13, 1960).

(9) FEDERAL RADIATION COUNCIL. Background materials for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

(10) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 5. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (July 1964).

(11) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, protective action guides for strontium–89, strontium–90, and cesium–137, Report No. 7. Superindent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1965).

(12) PORTER, C. R., C. R. PHILLIPS, M. W. CARTER, and B. KAHN. The cause of relatively high cesium–137 concentrations in Tampa, Florida, milk. Radioecological Concentration Processes, Proceedings of an International Symposium held in Stockholm, April 25–29, 1966. Pergamon Press, New York, N.Y. (1966) pp. 95–101.

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and presented routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows:

Program	Period reported	Issue
California Diet Study	October–December 1968 and January–March 1969	May 1970
Connecticut Diet Study	July–December 1968 and January–June 1969	February 1970
Strontium–90 in Tri-City Diets, *HASL*	June–December 1969	June 1970

1. Radionuclides in Institutional Diet Samples October–December 1969 and Annual Summary 1969

Bureau of Radiological Health and
Food and Drug Administration

The determination of radionuclide concentrations in the diet constitutes an important element of an integrated program of environmental radiological surveillance and assessment. In recognition of the potential significance of the diet in contributing to total environmental radiation exposures, the Public Health Service initiated its Institutional Diet Sampling Program in 1961. This program is administered by the Bureau of Radiological Health with the assistance of the Office of Compliance, Food and Drug Administration (*1*).

The program was designed to provide estimates of the dietary intake of radionuclides in a selected population group ranging from children to young adults of school age. Initially, the program was conducted at eight institutions; as of January 1965, its scope had increased to boarding schools or institutions in fifty municipalities. These institutions ranged from financially well-to-do boarding schools to orphanages with severe economic limitations.

Subsequent experience with the diets of school children of various ages indicated that the number of institutions sampled could be selectively reduced. As of December 1969, 20 basic institutions and eight auxiliary institutions distributed geographically as shown in figure 1, are being sampled. The station at Chicago, Ill., was discontinued because of difficulty in locating a new institution. Previous results showed that the daily dietary intake of teenage girls and children from 9 to 12 years of age were comparable, while teenage boys consumed 20 percent more food per day (*1–2*). Consequently, estimates for boys and/or girls can be calculated on the basis of the dietary intakes of children.

In general, the sampling procedure is the same at each institution. Each sample represents the edible portion of the diet for a full 7-day week, (21 meals plus soft drinks, candy bars, or other

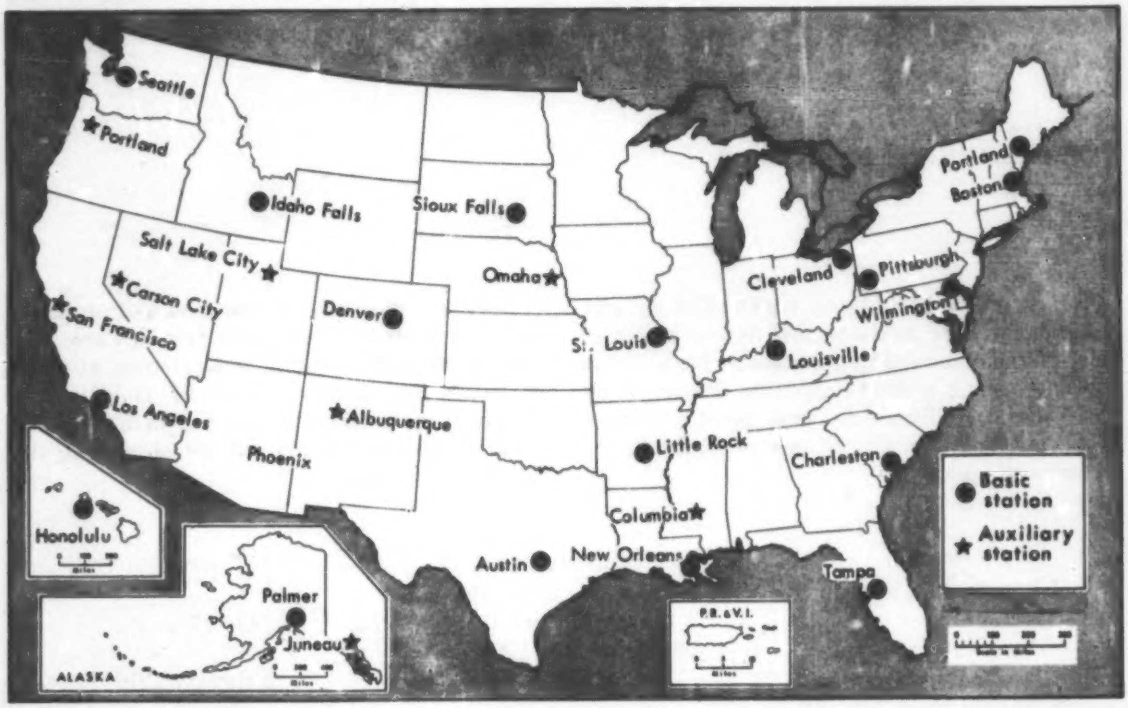
Seattle
Portland
Idaho Falls
Sioux Falls
Salt Lake City
Omaha
Carson City
Denver
San Francisco
St. Louis
Los Angeles
Albuquerque
Phoenix
Little Rock
Honolulu
Palmer
Juneau
ALASKA
Austin
New Orleans
Columbia
Portland
Boston
Cleveland
Pittsburgh
Wilmington
Louisville
Charleston
Tampa
P.R. & V.I.
● Basic station
★ Auxiliary station
Miles

Figure 1. Institutional diet sampling locations as of December 1969

Table 1. Concentration and intake of stable elements and radionuclides in institutional total diets of children (9–12 years of age), October–December 1969[a]

Location of institution	Month (1969)	Total weight (kg/day)	Calcium[b] (g/kg)	Calcium[b] (g/day)	Potassium (g/kg)	Potassium (g/day)	Strontium-89[b] (pCi/kg)	Strontium-89[b] (pCi/day)	Strontium-90[b] (pCi/kg)	Strontium-90[b] (pCi/day)	Cesium-137 (pCi/kg)	Cesium-137 (pCi/day)
Alaska: Palmer	Oct	1.23	0.6	0.8	1.4	1.7	0	0	7	9	0	0
	Nov	1.65			1.0	1.7					0	0
	Dec	1.10			1.7	1.8					16	18
Ariz: Phoenix	Oct	2.04	.6	1.1	1.0	2.0	0	0	3	6	0	0
	Nov	1.81			1.7	3.0					0	0
	Dec	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Ark: Little Rock	Oct	1.14	.7	1.0	1.5	1.7	NA	NA	7	10	0	0
	Nov	1.22			1.5	1.8					11	14
	Dec	1.80			1.5	2.9					16	20
Calif: Los Angeles	Oct[c]	1.79	.4	.6	1.0	1.8	0	0	2	3	0	0
	Nov[c]	1.60			1.0	1.6					0	0
	Dec[c]	1.28			1.2	1.6					0	0
Del: Wilmington	Oct	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Nov	2.08	.7	1.5	1.5	3.1	NA	NA	7	16	0	0
	Dec	2.36			1.4	3.3					12	26
Fla: Tampa	Oct	1.33	.7	1.0	1.3	1.7	NA	NA	7	10	28	31
	Nov	1.31			1.5	2.0					28	37
	Dec[c]	1.84			1.6	2.5					20	31
Hawaii: Honolulu	Oct[c]	2.11	.3	.6	1.3	2.8	0	0	0	0	0	0
	Nov	2.13			1.4	2.9					0	0
	Dec	2.23			1.3	2.9					0	0
Idaho: Idaho Falls	Oct[c]	2.06	.9	1.7	1.4	2.9	NA	NA	7	14	0	0
	Nov[c]	1.95			1.7	3.3					13	25
	Dec[c]	1.86			1.6	3.0					14	26
Ky: Louisville	Oct	2.57	.7	1.7	1.5	3.9	NA	NA	8	10	14	30
	Nov	2.47			1.5	3.7					0	0
	Dec	2.48			1.6	4.0					12	20
La: New Orleans	Oct[c]	2.01	.6	1.2	1.5	3.0	0	0	7	14	0	0
	Nov	1.93			1.6	3.0					14	27
	Dec	2.15			1.5	3.2					0	0
Maine: Portland	Oct	1.53	.8	1.3	1.5	2.3	NA	NA	9	.	13	19
	Nov	1.54			1.5	2.3					16	25
	Dec	1.45			1.7	2.5					26	28
Mass: Boston	Oct	2.05	.6	1.4	1.8	3.7	0	0	5	11	12	25
	Nov	2.22			1.7	3.8					15	23
	Dec	1.96			1.5	2.9					14	27
Mo: St. Louis	Oct	2.59	.9	2.2	1.9	4.0	NA	NA	7	17	0	0
	Nov	2.07			1.9	3.0					0	0
	Dec[c]	2.67			1.8	4.8					11	20
Ohio: Cleveland	Oct	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Nov	1.38	.7	1.0	1.5	2.1	NA	NA	6	9	0	0
	Dec	1.61			1.6	2.6					11	16
Pa: Pittsburgh	Oct	2.35	.5	1.1	1.4	3.3	NA	NA	5	11	0	0
	Nov	2.23			1.4	3.1					11	25
	Dec	2.23			1.4	3.1					12	27
S.C: Charleston	Oct	1.88	.8	1.6	1.4	2.6	0	0	7	14	14	26
	Nov	2.29			1.6	3.7					20	46
	Dec	1.81			1.5	2.8					15	27
S. Dak: Sioux Falls	Oct	1.61	.8	1.2	1.4	2.3	NA	NA	8	12	0	0
	Nov	1.46			1.5	2.2					11	16
	Dec	1.27			1.5	1.9					12	15
Tex: Austin	Oct[c]	1.64	.3	1.6	1.5	2.5	NA	NA	4	9	0	0
	Nov[c]	2.41			1.5	3.7					0	0
	Dec[c]	2.13			1.5	3.2					0	0
Wash: Seattle	Oct[c]	1.96	.5	1.0	1.6	3.1	0	0	6	12	0	0
	Nov[c]	2.04			1.4	2.9					0	0
	Dec[c]	1.93			1.5	2.9					0	0
Institutional average	Oct	1.85	0.7	1.2	1.5	2.7	0	0	6	11	7	12
	Nov	1.85			1.5	2.8					8	14
	Dec	1.86			1.5	2.8					12	21

[a] Iodine-131 and barium-140 were not detected at these stations during this period.
[b] Composite analysis of quarterly samples for each station.
[c] Since food samples were collected from two or more children who were not between the ages of 9 to 12, the gamma analyses for this month were not used in the institutional average. All chemistry data were included in the institutional average since this analysis was a composite of three or less individual samples.
NA, no analysis.
NS, no sample.

in-between snacks) obtained by duplicating the meals of a different individual each day. Drinking water, not included in the samples, is also sampled periodically. Each daily sample is kept frozen until the end of the collection period and is then packed in dry ice and shipped by air express to either the Southwestern Radiological Health Laboratory, Las Vegas, Nev; the Southeastern Radiological Health Laboratory, Montgomery, Ala; or the Northeastern Radiological Health Laboratory, Winchester, Mass. A detailed decription of sampling and analytical procedures was presented earlier (*3*).

Results

Table 1 presents the analytical results for institutional diet samples collected from October through December 1969, for children 9 to 12 years of age. The stable elements, calcium and

Table 2. Concentrations and intake of stable elements and radionuclides in institutional total diets of individuals (auxiliary stations), October–December 1969[a]

Location of institution		Month (1969)	Total weight (kg/day)	Calcium[b]		Potassium		Strontium-89[b]		Strontium-90[b]		Cesium-137	
				(g/kg)	(g/day)	(g/kg)	(g/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)
Alaska:	Juneau	Oct	1.05	0.4	0.5	1.4	1.4	0	0	4	4	13	14
		Nov	1.26			1.8	2.3					0	0
		Dec	1.35			1.3	2.4					35	47
Calif:	San Francisco	Oct	2.18	.4	.8	1.4	3.1	0	0	2	5	0	0
		Nov	2.17			1.5	3.1					0	0
		Dec	2.28			1.4	3.2					0	0
Miss:	Columbia	Oct	2.62	.9	1.9	1.4	3.6	NA	NA	6	14	0	0
		Nov	1.94			1.6	3.0					0	0
		Dec	2.06			1.5	3.0					12	15
Nebr:	Omaha	Oct	2.31	.9	2.0	1.7	3.9	NA	NA	5	11	0	0
		Nov	2.36			1.6	3.8					0	0
		Dec	2.08			1.7	3.5					11	23
Nev:	Carson City	Oct	1.71	.6	.8	1.4	2.4	0	0	4	5	0	0
		Nov	1.29			1.5	1.9					0	0
		Dec	1.08			1.9	1.9					0	0
N. Mex:	Albuquerque	Oct	2.00	.9	2.0	1.7	3.4	NA	NA	4	8	0	0
		Nov	2.36			1.5	3.6					16	38
		Dec	2.44			1.3	3.1					0	0
Oreg:	Portland	Oct	1.78	.6	1.1	2.3	4.1	0	0	7	14	13	23
		Nov	2.21			2.0	4.4					12	27
		Dec	1.85			1.6	3.0					0	0
Utah:	Salt Lake City	Oct	2.74	.5	1.4	1.1	2.9	0	0	2	6	0	0
		Nov	2.80			1.0	2.8					0	0
		Dec	2.68			1.3	3.4					0	0
Institutional average		Oct	2.06	0.6	1.3	1.5	3.1	0	0	4	8	3	5
		Nov	2.05			1.6	3.1					4	8
		Dec	1.97			1.6	2.9					7	12

[a] Iodine-131 and barium-140 were not detected at these stations during this period.
[b] Composite analysis of quarterly samples for each station.
NA, no analysis.

potassium, are reported in g/kg of diet, and the radionuclide concentrations of these samples, reported in pCi/kg of diet, are corrected for radioactive decay to the midpoint of the sample collection period, where applicable. Dietary intakes in g/day or pCi/day were obtained by multiplying the food consumption rate in kg/day by the appropriate concentration values. The average food consumption rate during this period was 1.86 kg/day compared to the network average of 1.87 kg/day observed from 1961 through 1968.

Strontium–90 dietary intake during this period averaged 6 pCi/day. This result falls within Range I as defined by the Federal Radiation Council (4). Cesium–137 intakes averaged 9 pCi/day during this period. Strontium–89, barium–140, and iodine–131 concentrations were below detectable levels.

All concentrations that are less than or equal to the appropriate minimum detectable level are reported as zero. The minimum detectable concentration is defined as the measured concentration equal to the 2-standard deviation analytical error. Accordingly, the minimum detectable limits are as follows:

Strontium–89	5 pCi/kg
Strontium–90	2 pCi/kg
Iodine–131	10 pCi/kg
Barium–140	10 pCi/kg
Cesium–137	10 pCi/kg

Data from eight auxiliary stations are included in a separate table for general information. This is presented in table 2. These stations do not meet the criterion that the majority of the samples are collected from children who range in age from 9–12 years. In order to supplement the existing environmental monitoring networks of the Bureau of Radiological Health, these eight institutions are being sampled in the same manner as the basic stations.

Annual averages

Annual average radionuclide concentrations and intakes are presented in tables 3 and 4 for the basic and auxiliary stations. During 1969, the annual average intake for the basic stations was 1.87 kg/day as compared to 1.98 kg/day in the auxiliary stations. The levels of radionuclide concentrations in both the basic and auxiliary stations were similar.

Table 3. 1969 annual average concentration and intake of stable elements and radionuclides in institutional total diets of children (9–12 years of age) [a]

Location of institution		Total weight (kg/day)	Calcium[b]		Potassium		Strontium-90[b]		Cesium-137		Radium-226[c]	
			g/kg	g/day	g/kg	g/day	pCi/kg	pCi/day	pCi/kg	pCi/day	pCi/kg	pCi/day
Alaska:	Palmer	1.47	0.6	0.8	1.3	1.8	6	8	6	7	0.4	0.6
Ariz:	Phoenix	1.83	.6	1.1	1.5	2.7	2	4	0	0	.4	.7
Ark:	Little Rock	1.40	.5	.8	1.4	2.0	8	11	9	12	.6	.8
Calif:	Los Angeles[d]	1.61	.4	.7	1.1	1.7	2	3	0	0	.4	.8
Colo:	Denver	2.22	.8	1.7	1.4	3.0	6	13	0	0	.7	1.6
Del:	Wilmington	2.17	.6	1.5	1.6	3.6	7	15	6	14	.6	1.3
Fla:	Tampa	1.33	.6	.8	1.4	2.0	7	9	28	37	.8	1.0
Hawaii:	Honolulu	2.54	.4	.9	1.4	3.6	3	8	9	25	.4	1.2
Idaho:	Idaho Falls[d]	2.01	1.0	2.1	1.6	3.3	8	16	10	20	.6	1.2
Ky:	Louisville	2.29	.7	1.6	1.6	3.7	9	19	6	14	.7	1.5
La:	New Orleans	2.00	.5	1.1	1.6	3.2	9	18	4	8	.4	.8
Maine:	Portland	1.69	.8	1.4	1.7	2.9	11	18	24	41	.6	1.1
Mass:	Boston	2.12	.6	1.3	1.8	3.8	8	16	18	36	.6	1.2
Mo:	St. Louis[d]	2.43	1.0	2.4	1.8	4.4	8	20	5	8	.0	2.6
Ohio:	Cleveland	1.60	.7	1.1	1.8	2.8	7	11	4	7	.6	1.0
Pa:	Pittsburgh	2.27	.5	1.2	1.4	3.2	7	16	5	11	.7	1.5
S.C:	Charleston	1.66	.7	1.1	1.4	2.4	9	14	16	25	.6	1.0
S. Dak:	Sioux Falls	1.47	.7	1.1	1.4	2.0	7	10	4	5	.8	1.2
Tex:	Austin[d]	1.93	.8	1.6	1.5	3.0	4	8	0	0	.4	.8
Wash:	Seattle[d]	1.92	.6	1.1	1.5	2.9	6	11	5	12	.5	1.0
Institutional average		1.87	0.6	1.2	1.5	3.0	7	13	9	16	0.6	1.1

[a] Strontium-89, iodine-131, and barium-140 were not detected at most stations during the year 1969. The exceptions are as follows:
January: 6 pCi/kg of strontium-89 was reported in Phoenix, Ariz.
February: 12 pCi/kg of iodine-131 was reported in Pittsburgh, Pa.
July: 6 pCi/kg of strontium-89 was reported in Boston, Mass.

[b] Composite analysis of quarterly samples for last 6 months of year.

[c] Radium analyses were only conducted for first 6 months of year.

[d] Since food samples were collected from two or more children who were not between the ages of 9 to 12, the gamma analyses were not used in the institutional average. All chemistry data were included in the institutional average since this analysis for the last 6 months of the year was a composite of three or less individual samples.

Table 4. 1969 annual average concentration and intake of stable elements and radionuclides in institutional total diets of individuals (auxiliary stations) [a]

Location of institution		Total weight (kg/day)	Calcium[b]		Potassium		Strontium-90[b]		Cesium-137		Radium-226[c]	
			g/kg	g/day	g/kg	g/day	pCi/kg	pCi/day	pCi/kg	pCi/day	pCi/kg	pCi/day
Alaska:	Juneau	1.19	0.5	0.7	1.5	1.8	8	9	12	14	0.4	0.6
Calif:	San Francisco	2.15	.5	1.1	1.5	3.2	3	7	2	5	.4	.9
Miss:	Columbia	2.16	.9	2.0	1.5	3.3	8	18	15	32	.6	1.2
Nebr.	Omaha	2.32	.9	1.9	1.7	4.0	6	13	4	9	.8	1.8
Nev:	Carson City	1.48	.7	1.0	1.4	2.0	3	5	3	5	.5	.5
N. Mex:	Albuquerque	2.38	.8	2.0	1.5	3.6	3	7	2	5	.4	1.0
Oreg:	Portland	1.84	.6	1.0	1.9	3.4	5	10	3	6	.5	.9
Utah:	Salt Lake City	2.30	.5	1.2	1.2	2.7	2	6	1	2	.4	.8
Institutional average		1.98	0.7	1.4	1.5	3.0	5	9	5	10	0.5	1.0

[a] Strontium-89, iodine-131 and barium-140 were not detected at most stations during the year 1969. The exceptions are as follows:
January: 8 pCi/kg of strontium-89 was reported in Portland, Oreg.
July: 11 pCi/kg of strontium-89 was reported in Juneau, Alaska.
November: 12 pCi/kg of barium-140 was reported in Albuquerque, N. Mex.

[b] Composite analysis of quarterly samples for each station for the last 6 months of the year.

[c] Radium analyses were only conducted for first 6 months of year.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–March 1969 and Annual Summary 1968	October 1969
April–June 1969	January 1970
July–September 1969	June 1970

REFERENCES

(*1*) ANDERSON, E. C., D. J. NELSON, Jr. Surveillance for radiological contamination in foods. Amer J Public Health 52:1391–1400 (September 1962).

(*2*) PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH. Radionuclides in institutional total diet samples, January–March 1965. Radiol Health Data 6:548–554 (October 1965).

(*3*) PUBLIC HEALTH SERVICE, NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Radionuclides in institutional total diet samples, January–March 1968. Radiol Health Data Rep 9:557–560 (October 1968).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

SECTION II. WATER

The Public Health Service, the Federal Water Quality Administration and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

Water sampling program	Period reported	Issue
Minnesota	January–June 1969	January 1970
New York	January–June 1969	June 1970
North Carolina	January–December 1967	May 1969
Radiostrontium in tap Water, *HASL*	January–December 1969	July 1970
Tritium Network	July–December 1969	July 1970
Washington	July 1967–June 1968	June 1969

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[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies, Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Radioactivity in California Waters[1] July-December 1968

Bureau of Radiological Health
State of California Department of Public Health

Gross beta radioactivity in California domestic waters is monitored by the State of California's Bureau of Radiological Health. The importance of this program in the State's environmental surveillance activities stems from the fact that most of California's domestic water supplies are of surface origin.

Radioactivity in such water supplies consists of the natural radioactivity in surface streams, radioactivity added by the discharge of sewage or by industrial waste effluents, and radioactivity from fallout, particularly fallout into open terminal or distribution reservoirs. Present efforts consist of sampling raw and treated surface waters and well waters. It should be noted that except for large metropolitan water supplies, raw water sampling is being phased out and treated water sampling being substituted or continued. This procedural change is predicated upon sampling water at the point of consumption.

Most of the supplies sampled have, as a source, raw surface waters (figure 1), although a few wells, along with some water supplies that use infiltration galleries, are also sampled.

Monitoring of domestic water supplies is on a continuing basis, since it has not been possible to forecast levels of radioactivity in these supplies based upon levels in rain, snow, or surface streams. Under the present sampling schedule, monthly 500-ml samples are collected and the total solids analyzed for alpha and beta radioactivity. In addition, 3-liter samples are collected monthly for approximately 6 months and composited for specific radionuclide analysis on a semiannual basis.

Analytical procedures

Radionuclide analyses of water are carried out in the State's Sanitation and Radiation Laboratory. Measurements of alpha and alpha-plus-beta radioactivities are made with a low-background windowless gas-flow proportional counter. Counting methods used follow those recommended by the U.S. Public Health Service (*1*).

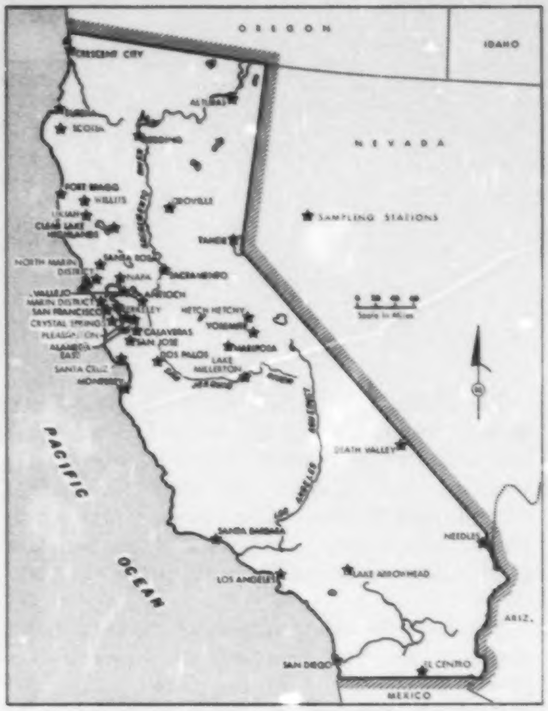
OREGON
IDAHO
NEVADA
SAMPLING STATIONS
CRESCENT CITY
ALTURAS
SCOTIA
FORT BRAGG
WILLITS
UKIAH
CLEAR LAKE HIGHLANDS
OROVILLE
TAHOE
NORTH MARIN DISTRICT
SANTA ROSA
NAPA
SACRAMENTO
VALLEJO
MARIN DISTRICT
SAN FRANCISCO
ANTIOCH
BERKELEY
HETCH HETCHY
YOSEMITE
CRYSTAL SPRINGS
PLEASANTON
CALAVERAS
ALAMEDA EAST
SAN JOSE
DOS PALOS
MARIPOSA
LAKE MILLERTON
SANTA CRUZ
MONTEREY
Scale in Miles
DEATH VALLEY
PACIFIC
OCEAN
SANTA BARBARA
NEEDLES
LOS ANGELES
LAKE ARROWHEAD
ARIZ.
SAN DIEGO
EL CENTRO
MEXICO

Figure 1. California surface water sampling stations

Individual samples are evaporated to dryness and the residue ashed at 450°C. The ashed sample is dissolved and transferred to an aluminum planchet for beta-particle counting. Specific radionuclides are determined semiannually on composite samples. Gamma-ray emitting nuclides are determined by gamma-ray spectroscopy and radium and radiostrontium by chemical separation and counting.

Discussion

Table 1 shows the monthly average beta radioactivity in the suspended-plus-dissolved solids in surface water supplies in California from July through December 1968. Following treatment, these waters are used for industrial and domestic

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[1] Data from January and April 1969 issues of Radiological Health News, State of California, Department of Public Health, Bureau of Radiological Health, 2151 Berkeley Way, Berkeley, Calif. 94704.

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Table 1. Gross beta radioactivity in California domestic waters, July–December 1968

Sampling station	Quality	Concentration (pCi/liter)					
		July	August	September	October	November	December
Alturas	Well	[a]13	[a]15	[a]8	39	NS	[a]11
Antioch	Treated	[a]4	[a]1	[a]2	[a]4	NS	[a]8
Berkeley	Treated	[a]3	34	[a]3	[a]6	[a]5	[a]9
Clearlake Highlands	Treated	[a]2	[a]15	[a]10	[a]6	[a]10	[a]12
Crescent City	Well	NS	[a]17	[a]6	[a]10	[a]8	NS
Death Valley	Treated	[a]31	[a]15	[a]21	[a]21	[a]17	[a]5
Dos Palos	Treated	ND	[a]6	[a]3	[a]10	NS	[a]14
El Centro	Treated	ND	[a]26	[a]10	NS	NS	NS
Eureka	Raw	31	[a]10	[a]9	0	[a]10	0
	Treated	[a]2	[a]3	ND	[a]7	[a]2	0
Fort Bragg	Treated	NS	NS	ND	ND	[a]4	ND
Lake Arrowhead	Treated	NS	NS	ND	[a]10	[a]13	ND
Lake Millerton	Raw	ND	29	ND	[a]7	0	[a]8
Los Angeles	Raw	NS	[a]14	NS	NS	NS	0
Marin Municipal Water District	Treated	[a]2	[a]9	ND	[a]9	[a]2	NS
Mariposa	Treated	ND	NS	NS	NS	NS	NS
Metropolitan Water District of Southern California:							
Weymouth Plant	Treated	52	65	[a]27	55	NS	93
Monterey	Treated	[a]11	ND	[a]1	NS	[a]8	NS
Napa	Treated	27	[a]13	[a]6	[a]7	[a]13	NS
Needles	Well	[a]26	[a]9	[a]1	NS	NS	NS
North Marin Water District	Treated	[a]10	18	[a]15	[a]7	[a]2	NS
	Raw	[a]4	[a]13	[a]19	[a]3	0	NS
	Sludge[b]	[a]23	[a]36	[a]72	[a]19	[a]25	NS
Oroville:							
Wyandotte Irrigation District	Treated	[a]4	ND	ND	[a]3	[a]13	0
Pleasanton	Well	[a]10	ND	ND	[a]6	[a]4	[a]8
Redding	Treated	NS	NS	NS	NS	NS	[a]5
Sacramento:							
American River	Treated	[a]8	[a]4	NS	[a]9	NS	[a]3
Sacramento	Treated	[a]9	ND	NS	[a]16	NS	0
San Diego	Raw	ND	ND	8	[a]13	[a]6	[a]24
	Treated	[a]18	NS	[a]20	[a]3	0	[a]3
San Francisco:							
Water Department	Raw	[a]1	18	[a]7	0	[a]3	[a]2
Alameda, East	Raw	[a]3	ND	[a]11	0	NS	0
Brightside Weir	Raw	[a]1	NS	[a]6	[a]2	NS	[a]5
Calaveras Reservoir	Raw	ND	[a]13	[a]8	0	[a]10	0
Crystal Springs	Raw	[a]2	NS	NS	NS	NS	[a]9
Hetch Hetchy	Raw	[a]7	NS	NS	NS	NS	NS
San Jose	Raw	ND	[a]8	ND	0	[a]8	NS
Santa Barbara	Treated	[a]14	[a]2	[a]2	[a]14	[a]12	[a]6
Santa Cruz	Raw	ND	ND	[a]7	[a]7	NS	[a]4
Santa Rosa	Raw	31	ND	ND	0	[a]3	0
Scotia	Raw	[a]17	[a]5	[a]20	[a]3	[a]5	0
Tahoe City	Raw	NS	NS	ND	NS	NS	NS
Ukiah	Well	ND	NS	ND	[a]1	NS	NS
Vallejo:							
Fleming Hill	Raw	[a]4	ND	[a]3	[a]5	[a]6	[a]17
	Treated	ND	[a]8	[a]9	[a]9	[a]8	0
Willits	Treated	[a]7	ND	61	0	0	NS
Yosemite	Treated	[a]7	[a]13	[a]5	[a]6	0	[a]16
Maximum		52	65	61	55	17	93
Minimum		1	1	1	0	0	0

[a] When the counting rate of the sample is not equal to at least twice the 0.95 error, the value reported is the best estimate, but is not statistically significant.

[b] Sludge reported in pCi/g (dry weight).

NS, no sample collected.

ND, no detectable activity.

purposes. Because alpha radioactivity in water has, in general, been undetectable or very slight, alpha radioactivity analyses are not presented. Radioactivity or very slight, alpha radioactivity analyses are not presented. Radioactivity in surface water remains low. No increase has been observed in drinking water because of the testing of nuclear devices during the past several years.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1968	December 1969

REFERENCE

(*1*) PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH. Radionuclide analyses of environmental samples, R 59-6. Radiological Health Research Activities, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio 45226 (November 16, 1959).

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta-radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports.*

Network	Period	Issue
Fallout in the United States and Other Areas, HASL	January–June 1968	October 1969
Plutonium in Airborne Particulates and Precipitation	July–December 1969	June 1970
Tritium in Precipitation	July–December 1969	July 1970

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1. Radiation Alert Network
April 1970

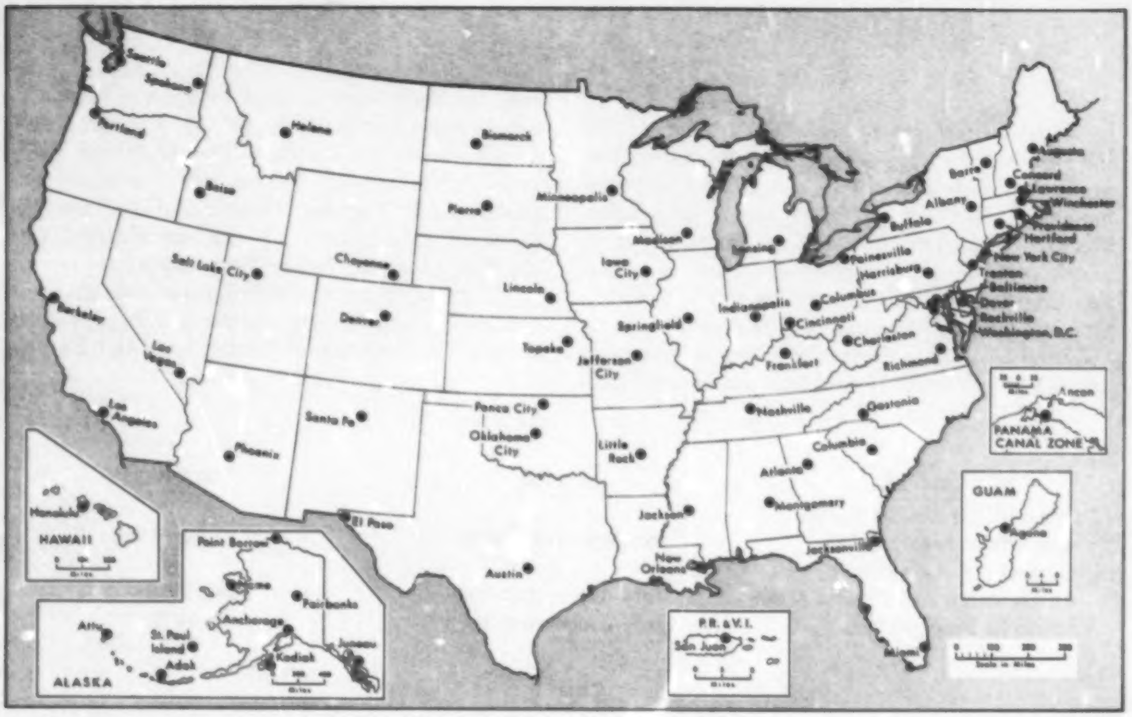
Bureau of Radiological Health
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 73 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate Bureau of Radiological Health officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Radiological Surveillance Branch, Division of Environmental Radiation, BRH, Rockville, Md. A detailed description of the sampling and analytical procedures was presented in the April 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation as measured by the field estimate technique during April 1970. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting station.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Helena
Bismarck
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Cheyenne
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Lincoln
Denver
Berkeley
Las Vegas
Topeka
Springfield
Indianapolis
Columbus
Cincinnati
Jefferson City
Frankfort
Charleston
Richmond
Los Angeles
Santa Fe
Ponca City
Oklahoma City
Phoenix
Little Rock
Nashville
Gastonia
Columbia
Atlanta
Montgomery
Jackson
El Paso
Austin
New Orleans
Jacksonville
Miami
Augusta
Barre
Concord
Lawrence
Winchester
Albany
Buffalo
Providence
Hartford
Painesville
Harrisburg
New York City
Trenton
Baltimore
Dover
Rockville
Washington, D.C.
Ancon
PANAMA CANAL ZONE
GUAM
Agana
P.R. & V.I.
San Juan
HAWAII
Honolulu
Point Barrow
Nome
Fairbanks
Anchorage
Attu
St. Paul Island
Adak
Kodiak
Juneau
ALASKA
Miles
Scale in Miles

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, April 1970

Station location		Air surveillance				Last profile in RHD&R	Precipitation				
		Number of samples	Gross beta radioactivity (pCi/m³)				Number of samples	Total depth (mm)	Field estimation of deposition		
			Maximum	Minimum	Average[a]				Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	22	6	0	2	Dec 69	3	61	3	61	20
Alaska:	Adak	(b)				Dec 69	(c)				
	Anchorage	(b)				June 70	(c)				
	Attu Island	20	0	0	0	Jan 70	(c)				
	Fairbanks	15	1	0	0	July 70	1	2	1	2	1
	Juneau	(b)				Oct 69	(c)				
	Kodiak	7	0	0	0	Nov 69	(c)				
	Nome	6	1	0	1	Mar 70	(c)				
	Point Barrow	28	1	0	0	Feb 70	(c)				
	St. Paul Island	(b)				Apr 70	(c)				
Ariz:	Phoenix	14	12	1	4	Oct 69	(c)				
Ark:	Little Rock	10	2	0	1	June 70	(c)				
Calif:	Berkeley	22	1	0	0	Nov 69	(c)				
	Los Angeles	21	3	0	1	Mar 70	(c)				
C.Z:	Ancon	17	0	0	0	Nov 69	(c)				
Colo:	Denver	22	6	1	3	Nov 69	4	31	(d)		
Conn:	Hartford	22	1	0	1	July 70	7	81	7	81	3
Del:	Dover	21	1	0	0	May 70	(c)				
D.C:	Washington	20	1	0	0	Feb 70	(c)				
Fla:	Jacksonville	22	2	0	1	June 70	4	51	4	51	13
	Miami	16	1	0	0	July 70	1	7	1	7	0
Ga:	Atlanta	21	1	1	1	Apr 70	1	74	1	74	37
Guam:	Agana	(b)				May 70	(c)				
Hawaii:	Honolulu	25	1	0	1	Jan 70	7	51	(d)		
Idaho:	Boise	22	3	1	2	Jan 70	6	28	6	28	4
Ill:	Springfield	20	4	0	2	Feb 70	(c)				
Ind:	Indianapolis	(b)				Apr 70	(c)				
Iowa:	Iowa City	20	6	0	2	Nov 69	6	76	6	76	3
Kans:	Topeka	21	5	0	2	June 70	4	69	4	69	3
Ky:	Frankfort	(b)				Feb 70	(c)				
La:	New Orleans	14	1	0	1	Feb 70	7	23	(d)		
Maine:	Augusta	22	2	0	1	Mar 70	3	118	3	118	0
Md:	Baltimore	22	1	0	1	July 70	9	76	9	76	21
	Rockville	15	2	0	1	Jan 70	(c)				
Mass:	Lawrence	21	1	0	1	May 70	5	88	5	88	12
	Winchester	22	2	0	1	Dec 69	7	95	7	95	0
Mich:	Lansing	20	1	0	0	Jan 70	7	36	7	36	6
Minn:	Minneapolis	22	2	0	1	May 70	5	106	5	106	24
Miss:	Jackson	15	1	0	1	Mar 70	2	65	2	65	9
Mo:	Jefferson City	21	3	0	1	Apr 70	9	143	9	143	0
Mont:	Helena	18	2	0	1	Dec 69	1	9	1	9	15
Nebr:	Lincoln	15	7	1	3	Apr 70	4	58	4	58	12
Nev:	Las Vegas	13	2	1	1	July 70	(c)				
N.H:	Concord	(b)				Feb 70	(c)				
N.J:	Trenton	19	3	0	1	Mar 70	7	113	7	113	9
N. Mex:	Santa Fe	18	3	0	1	Dec 69	3	9	3	9	0
N.Y:	Albany	(b)				Apr 70	1	9	1	9	6
	Buffalo	21	2	0	1	Nov 69	(c)				
	New York City	15	1	0	0	Dec 69	(c)				
N.C:	Gastonia	18	9	1	4	Nov 69	3	30	(d)		
N. Dak:	Bismarck	22	2	0	1	Feb 70	9	166	9	166	10
Ohio:	Cincinnati	(b)				May 70	(c)				
	Columbus	4	2	1	1	Mar 70	(c)				
	Painesville	(b)				July 70	4	40	3	21	9
Okla:	Oklahoma City	(b)				Jan 70	(c)				
	Ponca City	22	5	0	1	July 70	8	96	8	96	1
Oreg:	Portland	22	4	0	1	Apr 70	13	97	13	97	3
Pa:	Harrisburg	15	1	0	0	Apr 70	3	54	3	54	16
P.R:	San Juan	(b)				Mar 70	(c)				
R.I:	Providence	19	2	0	1	Jan 70	3	80	3	80	9
S.C:	Columbia	19	3	0	1	Dec 69	3	73	3	73	5
S. Dak:	Pierre	13	6	1	3	Oct 69	(c)				
Tenn:	Nashville	22	2	0	1	Jan 70	8	148	8	148	12
Tex:	Austin	16	4	0	2	May 70	(c)				
	El Paso	(b)				Feb 70	(c)				
Utah:	Salt Lake City	30	4	0	2	Mar 70	9	63	9	63	7
Vt:	Barre	19	3	0	1	June 70	6	76	6	76	12
Va:	Richmond	21	1	0	0	June 70	6	45	6	45	10
Wash:	Seattle	25	0	0	0	June 70	10	53	(d)		
	Spokane	22	2	0	1	May 70	(c)				
W. Va:	Charleston	22	3	0	1	Dec 69	11	78	11	78	16
Wisc:	Madison	22	4	0	1	June 70	7	73	7	73	8
Wyo:	Cheyenne	22	3	0	1	July 70	1	1	1	1	0
Network summary		1,122	12	0	1		5	65	5	68	9

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] No report received. (Air samples received without field estimate data are not considered by the data program.)
[c] No precipitation sample collected.
[d] This station is part of the plutonium in precipitation network. No gross beta measurements are done.

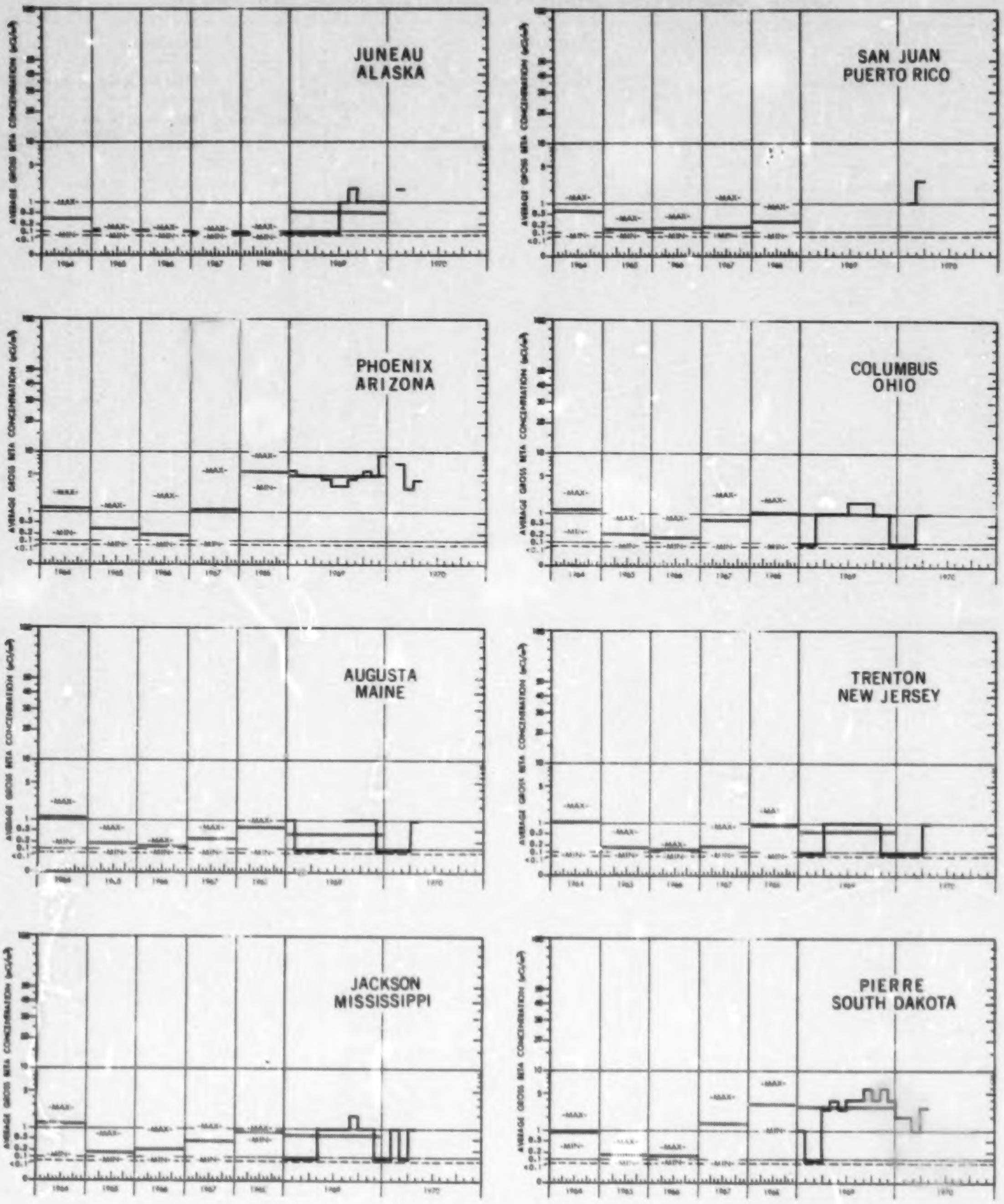

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1964–April 1970

2. Canadian Air and Precipitation Monitoring Program[1], April 1970

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for April 1970 are presented in table 2.

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[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, April 1970

Station	Number of samples	Air surveillance, gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	30	0.6	0.1	0.2	16	0.6
Coral Harbour	27	.3	.1	.2	NS	NS
Edmonton	30	.4	.1	.2	260	1.1
Ft. Churchill	30	.2	.1	.1	123	.6
Fredericton	30	.5	.1	.2	54	4.9
Goose Bay	28	.2	.0	.1	31	1.9
Halifax	30	.5	.0	.2	86	5.2
Inuvik	28	.2	.1	.1	43	.4
Montreal	30	.5	.0	.2	106	6.7
Moosonee	30	.3	.0	.1	53	1.7
Ottawa	29	.4	.0	.2	68	4.0
Quebec	30	.3	.0	.2	62	4.6
Regina	30	.3	.0	.2	32	1.4
Resolute	30	.2	.1	.2	13	.1
St. John's, Nfld	28	.4	.0	.1	19	2.8
Saskatoon	28	.3	.1	.2	NS	NS
Sault Ste. Marie	29	.5	.0	.2	144	5.2
Thunder Bay	29	.4	.1	.2	98	10.3
Toronto	29	.6	.1	.3	96	7.9
Vancouver	30	.3	.0	.1	58	6.6
Whitehorse	30	.2	.0	.1	38	.5
Windsor	29	.5	.1	.2	107	8.6
Winnipeg	30	.4	.1	.2	66	4.3
Yellowknife	27	.2	.1	.2	202	1.1
Network summary	701	0.6	0.0	0.2	81	3.7

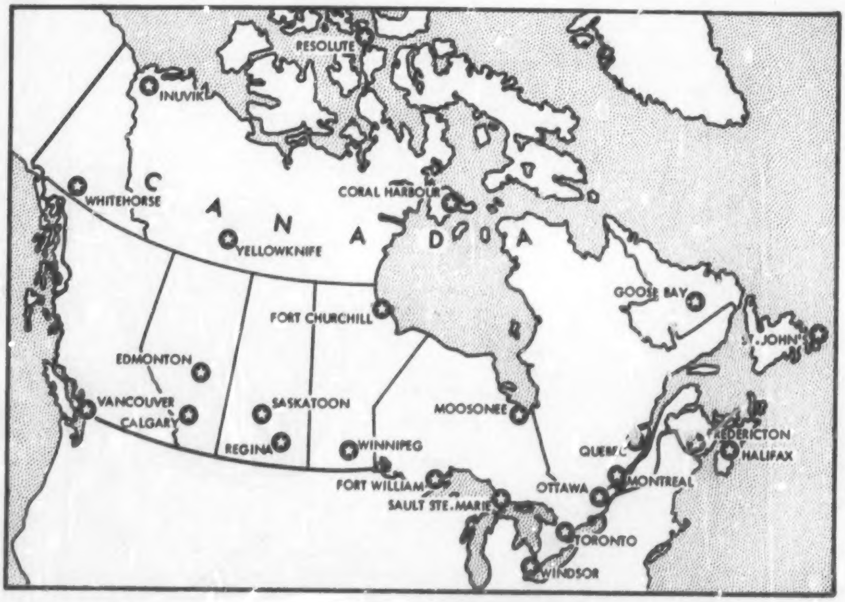
RESOLUTE
INUVIK
C
WHITEHORSE
A
N
A
D
A
YELLOWKNIFE
CORAL HARBOUR
GOOSE BAY
FORT CHURCHILL
ST. JOHN'S
EDMONTON
VANCOUVER
CALGARY
SASKATOON
REGINA
WINNIPEG
MOOSONEE
FREDERICTON
HALIFAX
QUEBEC
FORT WILLIAM
SAULT STE. MARIE
OTTAWA
MONTREAL
TORONTO
WINDSOR

Figure 3. Canadian air and precipitation sampling stations

3. Mexican Air Monitoring Program
December 1969

National Commission of Nuclear Energy
Mexico, D.F.

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), México, D.F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the Division of Radiological Protection was restructured and its name changed to Dirección General de Seguridad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D.F.; Mérida; Veracruz; San Luis Potosí; and Ensenada. Staff members of the DRS operate the station at México, D.F., while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department of the University of Mérida, the Institute de Zonas Desérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air through a high-efficiency 6 by 9-inch glass-fiber filter for 20 hours a day, 3 or 4 days a week at the rate of 1,000 cubic meters per day using high volume samplers.

After each 20-hour sampling period, the filter is removed and shipped via airmail to the Sección de Radioactividad Ambiental, CNEN, in México, D.F., for assay of gross beta radioactivity, allowing a minimum of 3 or 4 days after collection for the decay of radon and thoron daughters. The data are not extrapolated to the time of collection. Statistically, it has been found that a minimum of five samples per month was needed to get a reliable average radioactivity at each station (*6*).

The maximum, minimum, and average beta radioactivity in surface air during December 1969 is presented in table 3.

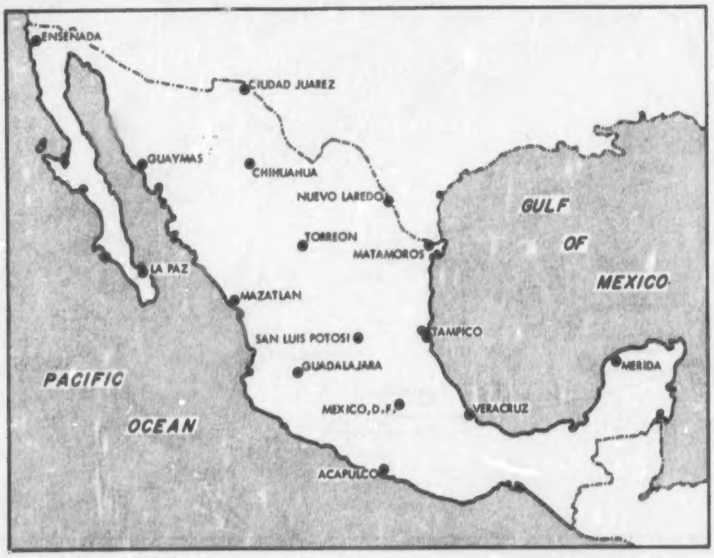

Figure 4. Mexican air sampling locations

Table 3. Mexican gross beta radioactivity of airborne particulates, December 1969

Station	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Acapulco	NS			
Chihuahua	7	0.2	0.1	0.1
Ciudad Juares	6	.3	.1	.2
Ensenada	NS			
Guadalajara	NS			
Guaymas	NS			
La Paz	12	.3	.1	.2
Matamoros	NS			
Mazatlán	NS			
Mérida	11	.3	.1	.2
México, D.F.	7	.1	<.1	.1
Nuevo Laredo	5	.11	.1	.1
San Luis Potosí	NS			
Tampico	NS			
Torreón	5	.4	.1	.2
Veracruz	NS			

NS, no sample, station temporarily shutdown.

4. Pan American Air Sampling Program April 1970

Pan American Health Organization and *U.S. Public Health Service*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 5. Analytical techniques were described in the January 1968 issue of *Radiological Health Data and Reports*. The April 1970 air monitoring results from the participating countries are given in table 4.

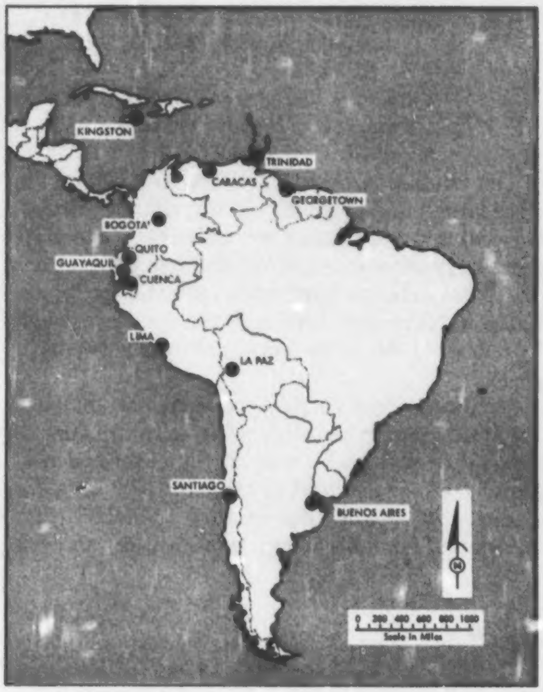

Figure 5. Pan American Air Sampling Program stations

Table 4. Summary of gross beta radioactivity in Pan American surface air, April 1970

Station	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average[a]
Argentina: Buenos Aires	NS			
Bolivia: La Paz	NS			
Chile: Santiago	20	0.19	0.02	0.06
Colombia: Bogota	28	.13	.00	.06
Ecuador: Cuenca	NS			
Guayaquil	NS			
Quito	NS			
Guyana: Georgetown	13	.37	.11	.24
Jamaica: Kingston	NS			
Peru: Lima	26	.07	.02	.04
Venezuela: Caracas	20	.50	.09	.26
West Indies: Trinidad	12	.28	.12	.19
Pan American summary	119	0.50	0.00	0.12

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Reported values of less than 0.005 pCi/m³ are considered as 0.00 pCi/m³ in averaging.

NS, no sample.

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5. Plutonium in Airborne Particulates January–March 1969

Bureau of Radiological Health
U.S. Public Health Service

The Radiation Alert Network (RAN) of the Bureau of Radiological Health, Public Health Service, routinely analyzes airborne particulate samples from selected RAN stations for plutonium. The airborne particulate analyses were initiated in November 1965, and the results through December 1968 have been previously reported (*7–18*).

Air filters from 11 RAN stations are analyzed for plutonium. A monthly composite is made of one-half of each individual air filter from each of the 11 stations and sent to the PHS Northeastern Radiological Health Laboratory (NERHL) for analysis. The laboratory reduced this analysis on filters to quarterly composites as of the August 1968 sample. They also discontinued analysis of precipitation for plutonium due to consistently low levels of plutonium in the environment after September 30, 1968.

The results for January through March 1969 are presented in table 5. ND (nondetectable) has been used to indicate samples containing plutonium–238 or plutonium–239 activities less than or equal to the appropriate minimum detectable activities (.020 pCi and .015 pCi per sample for plutonium–238 and plutonium–239, respectively). Sample size varies, generally ranging from 20,000 to 30,000 cubic meters of air for the air filter samples.

Table 5. Plutonium in airborne particulates, January–March 1969

	Anchorage	Phoenix	Denver	Honolulu	New Orleans	Rockville	Buffalo	Gastonia	Pierre	Austin	Seattle
Plutonium-238 (fCi/m³) January–March	.017	.018	.019	.008	.014	.011	.008	.013	.008	.013	.007
Plutonium-239 (fCi/m³) January–March	.065	.077	.071	.033	.058	.040	.036	.058	.033	.047	.032
^{239}Pu/^{238}Pu January–March	3.82	4.28	3.74	4.12	4.14	3.64	4.50	4.46	4.12	3.62	4.57

REFERENCES

(*1*) BIRD, P. M., A. E. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(*2*) BIRD, P. M., A. E. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(*3*) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW–RP–5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(*4*) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD–11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(*5*) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD–21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

(*6*) VASQUEZ, M. and R. M. DE NULMAN. Estudios sobre la radioactividad ambiental en la República Mexicana, 1963–1965. Comisión Nacional de Energía Nuclear, Dirección General de Seguridad Radiologica (1966).

(*7*) RUSSELL, J., H. LEVINE, R. SCHNEIDER. Plutonium in airborne particulates November 1965 through March 1966. Radiol Health Data Rep 7:483–484 (August 1966).

(*8*) DIVISION OF RADIOLOGICAL HEALTH. Plutonium in airborne particulates, April–June 1966. Radiol Health Data Rep 7:666–667 (November 1966).

(*9*) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Plutonium in airborne particulates, July–September 1966. Radiol Health Data Rep 8:108–109 (February 1967).

(*10*) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Plutonium in airborne particulates, October–December 1966. Radiol Health Data Rep 8:288–289 (May 1967).

(*11*) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Plutonium in airborne particulates, January–March 1967. Radiol Health Data Rep 8:534 (September 1967).

(*12*) LEVINE, H., W. P. KIRK, H. J. L. RECHEN. Plutonium and strontium-90 in precipitation, August 1966 through March 1967. Radiol Health Data Rep 8:574–576 (October 1967).

(*13*) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Plutonium in airborne particulates and precipitation and strontium-90 in precipitation, April–June 1967. Radiol Health Data Rep 8:662–663 (November 1967).

(*14*) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Plutonium in airborne particulates and precipitation, July–December 1967. Radiol Health Data Rep 9:761–763 (December 1968).

(*15*) BUREAU OF RADIOLOGICAL HEALTH. Plutonium in airborne particulates and precipitation, January–March 1968. Radiol Health Data Rep 10:34–35 (January 1969).

(*16*) BUREAU OF RADIOLOGICAL HEALTH. Plutonium in airborne particulates and precipitation, April–June 1968. Radiol Health Data Rep 10:464–466 (October 1969).

(*17*) BUREAU OF RADIOLOGICAL HEALTH. Plutonium in airborne particulates and precipitation, July–September 1968. Radiol Health Data Rep 11:92–93 (February 1970).

(*18*) BUREAU OF RADIOLOGICAL HEALTH. Plutonium in airborne particulates and precipitation, July–December 1968. Radiol Health Data Rep 11:311–312 (June 1970).

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual.[1]"

Summaries of the environmental radioactivity data follow for Atomics International, Neutron Devices Department, and Feed Materials Production Center.

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[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Atomics International.[2]
July–December 1969

North American Rockwell Corporation
Canoga Park, Calif.

Atomics International, a division of North American Rockwell Corporation, has engaged in atomic energy research and development since 1946. The company designs, develops, and constructs nuclear reactors for central station and compact power plants for medical, industrial, and scientific applications.

The company headquarters is located in Canoga Park, Calif., approximately 23 miles northwest of downtown Los Angeles. The 290-acre Nuclear Development Field Laboratory (Santa Susana Facility), equipped with extensive testing facilities for the support of advanced nuclear studies, is located in the Simi Hills of Ventura County, approximately 29 miles northwest of downtown Los Angeles. The location of the above sites in relation to nearby communities is shown in figure 1.

The basic concept of radiological hazard control at Atomics International requires adequate containment of radioactive materials and, through rigid operational controls, minimizes effluent releases and external radiation levels. The environmental monitoring program provides a measure of the effectiveness of the company's radiological safety procedures and of engineering safeguards incorporated into facility designs.

The onsite environs of Atomic International headquarters and Nuclear Development Field Laboratory (NDFL) are surveyed monthly to determine the concentration of radioactivity in typical surface soil, vegetation, and water samples. The offsite environs are sampled monthly, except for soil and vegetation which are sampled quarterly. In addition, continuous environmental air monitoring at the sites provides information

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[2] Summarized from "Environmental Monitoring, Semiannual Report, July 1, 1969 to December 31, 1969" Atomics International, Division of North American Rockwell Corporation.

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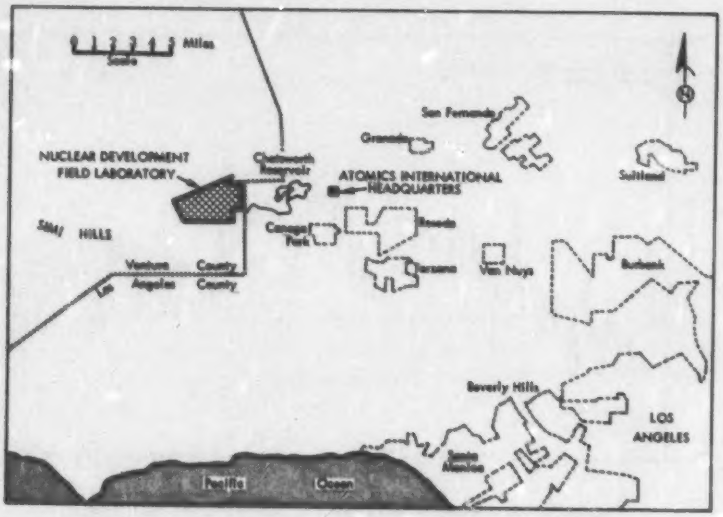
0 1 2 3 4 5 Miles
Scale
NUCLEAR DEVELOPMENT FIELD LABORATORY
Chatsworth Reservoir
ATOMICS INTERNATIONAL HEADQUARTERS
San Fernando
Granada
Sunland
Canoga Park
Reseda
Tarzana
Van Nuys
Burbank
SIMI HILLS
Ventura County
Los Angeles County
Beverly Hills
LOS ANGELES
Santa Monica
Pacific Ocean

Figure 1. Atomics International facilities and vicinity

concerning long-lived airborne particulate radioactivity.

Air monitoring

Environmental air sampling is conducted continuously at the headquarters and NDFL sites with automatic air samplers operating on 24-hour sampling cycles. Airborne particulate radioactivity is collected on HV-70 filter paper which is automatically changed at the end of each sampling period. The filter is removed from the sampler and counted after the radioactivity is allowed to decay for at least 72 hours. The volume of a typical daily environmental air sample is approximately 20 cubic meters. The average concentration of long-lived beta-gamma radioactivity on airborne particulates is presented in table 1 for July–December 1969.

Table 1. Beta-gamma radioactivity of airborne particulates, Atomics, July–December 1969

Location	Number of samples	Average concentration[a] (pCi/m³)
Headquarters	325	0.30
NDFL	1,150	.20

[a] Minimum detectable level—0.04 pCi/m³.

When abnormally high airborne radioactivities are observed, the radioactivity decay data are plotted to determine the presence of short-lived isotopes other than naturally occurring radon, thoron, and daughters. If fallout is suspected, the decay characteristics are observed. If the radioactivity decays as a function of $t^{-1.2}$, the data curve is extrapolated in order to determine the date of origin. This data is compared with the dates of publicized nuclear detonations to determine if the abnormal airborne radioactivity was caused by such detonations.

A graph of averaged long-lived airborne radioactivity concentrations detected at the Headquarters and NDFL facilities during the second half of 1969 is presented in figure 2. The graph shows the incidence of several sustained periods of increased airborne radioactivity during the year, with a generally increasing trend through the spring months and diminishing through the fall. No significant transient peaks were detected during 1969.

Water monitoring

Process water used at the NDFL is obtained from Ventura County Water District No. 10 and distributed onsite by the same piping system previously used when process water was supplied

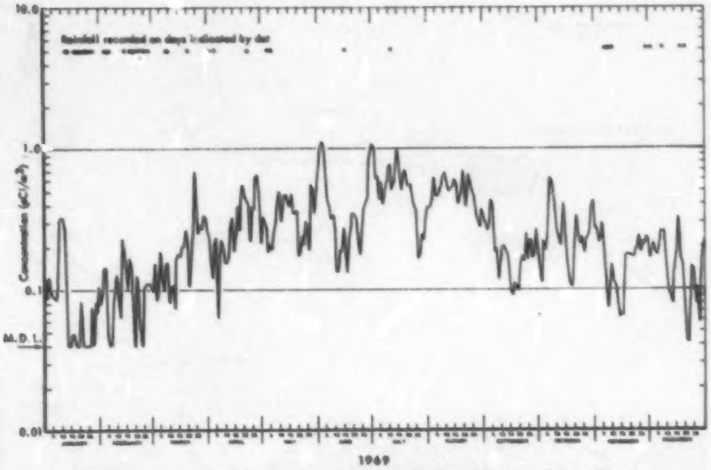

Figure 2. Long-lived airborne radioactivity at Atomics International, 1969

by onsite wells. Pressure is provided by elevated storage tanks, one 50,000-gallon and one 500,000-gallon tank onsite. While clinically potable, the water is not used for drinking. Bottled potable water is delivered by a vendor and is not analyzed. Water from the pipe system is sampled monthly at two locations. The average process water radioactivity concentration is presented in table 2.

Table 2. Process water radioactivity, NDFL site July–December 1969

Type of radioactivity	Number of samples	Average concentration (pCi/liter)
Alpha	12	0.06
Beta-gamma	12	5.5

Soil, vegetation, and water are sampled monthly at Chatsworth Reservoir which is operated by the Los Angeles City Department of Water and Power. Normally, one water sample is obtained from the lake surface and a second sample is obtained from the reservoir water supply inlet located on the north side of the lake. The lake was drained in July 1969 for construction, thereby precluding sampling for most of the last half of 1969. The average radioactivity for both surface and supply water samples is presented in table 3.

Surface discharged waters from NDFL facilities drain into holding reservoirs on adjacent property. When full, the main reservoir is drained into Bell Creek, a tributary of the Los Angeles River in the San Fernando Valley, Los Angeles County. Pursuant to the requirements of Los Angeles Regional Water Quality Control Board Resolution 66–49 of September 21, 1966, an environmental sampling station has been established in Bell Creek Canyon approximately 2.5 miles downstream from the south NDFL boundary. Samples, obtained and analyzed monthly, include stream bed mud, vegetation, and water. Average radioactivity concentrations in the main holding reservoir and Bell Creek samples are presented in table 4.

Table 3. Chatsworth Reservoir water radioactivity Atomics, July–December 1969

Sample	Type of radioactivity	Number of samples	Average concentration (pCi/liter)
Lake surface	Alpha	2	0.28
	Beta-gamma	2	8.0
Supply inlet	Alpha	6	.11
	Beta-gamma	6	4.7

Table 4. Radioactivity in the Rocketdyne reservoir and Bell Creek[a], July–December 1969

Sample description (units)	Number of samples	Alpha radioactivity	Beta radioactivity
Reservoir station 6 water[a] (pCi/liter)	6	0.05	6.9
Reservoir station 12 water[a] (pCi/liter)	6	.05	6.7
Bell Creek mud (pCi/g)	6	.28	25
Bell Creek vegetation (pCi/g ash)	6	.15	148
Bell Creek water (pCi/liter)	6	.03	4.0

[a] Location not shown on figure 1.

Soil and vegetation monitoring

Soil and vegetation are regularly sampled at 25 locations. Eleven sampling stations are located within the boundaries of Atomics International's sites and are referred to as "onsite" stations. The remaining 14 stations, located within a 10-mile radius of the sites, are referred to as "off-site" stations.

Surface soil types available for sampling range from decomposed granite to clay and loam. Samples are taken from the top half-inch layer of ground surface. The soil samples are packaged and sealed in plastic containers and returned to the laboratory for analysis. Radioactivity in soil samples is presented in table 5.

Table 5. Radioactivity in the soil, Atomics July–December 1969

Area	Type of radioactivity	Number of samples	Average concentration (pCi/g)
Onsite	Alpha	72	0.41
	Beta-gamma	72	27
Offsite	Alpha	24	.38
	Beta-gamma	24	25

Vegetation samples obtained in the field are of the same plant type wherever possible, generally, sunflower or wild tobacco plant leaves. These types maintain a more active growth rate during the dry season than do most natural vegetation indigenous to the local area. Vegetation leaves are stripped from plants and transferred to the laboratory for analysis. Plant root systems are not routinely sampled. Radioactivity in vegetation samples is presented in table 6.

Table 6. Radioactivity in vegetation, Atomics July–December 1969

Area	Type of radioactivity	Number of samples	Average concentration (pCi/g ash)
Onsite	Alpha	72	0.34
	Beta-gamma	72	171
Offsite	Alpha	24	.34
	Beta-gamma	24	146

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1968	July 1969
January–June 1969	March 1970

2. Feed Materials Production Center.[3]
July–December 1969

National Lead Company
Fernald, Ohio

The Feed Materials Production Center (FMPC) is operated by the National Lead Company of Ohio for the Atomic Energy Commission (AEC). The location as related to populated areas is shown in figure 3. Cincinnati and Hamilton, the larger nearby communities, are situated 20 and 10 miles from the center, respectively. Operations at this project deal with the processing of high-grade uranium concentrates to produce metallic uranium and with fabricating the metal into fuel elements.

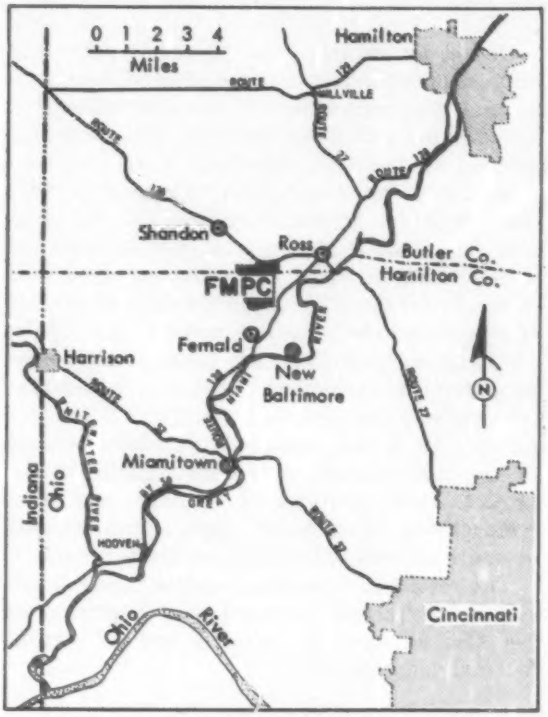

Figure 3. Areas map of Feed Materials Production Center

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[3] Summarized from "Feed Materials Production Center Environmental Monitoring Semiannual Report for the Second Half of 1969, Summary Report for 1969 (NLCO–1055).

During the past 2 years the project has also processed thorium to produce purified oxide and metal. The process of these products is essentially the same as used in producing uranium.

During the many involved reactions and processes that lead to the production of reactor fuels, various liquid and airborne wastes are generated. These wastes contain varying quantities of uranium and thorium. Various in-plant methods are used to curtail their release into the environment surrounding the plant. Almost complete removal of the materials is accomplished by using dust collectors and waste treatment processes. An environmental monitoring program has been established to determine the concentrations of plant materials in the water and air outside the project.

Air monitoring

Onsite air samples are obtained from four permanent perimeter air sampling stations, located at the four corners of the production area as shown in figure 4. Samples from these perimeter stations are collected once each week and analyzed for uranium and total radioactivity. Offsite samples are collected by a mobile air sampling unit. The location at which samples are collected is determined by local meteorological conditions on the day of sampling. Approximately 80 percent of all samples are taken downwind of the FMPC plant. Replicate samples are taken at each sampling point and averaged to obtain a representative concentration for that location. An analysis for thorium is not considered necessary because of the small amount of thorium handled in the project. Concentrations of uranium and total radioactivity of airborne particulates sampled at onsite and offsite locations are given in table 7.

The results of sampling indicate that the offsite concentrations averaged only 5 percent of the AEC standard for uranium and 0.2 percent for total radioactivity.

Water monitoring

Each of the individual production plants on the project has collection sumps and treatment equipment to remove the uranium from the process waste water. The effluent from the plants are collected at a general sump for additional treatment and settling. The clear water from the sump is pumped to the river. The solid portion is pumped to a chemical waste pit for further settling. The clear effluent from the pit is then combined with three other types of project waste water and discharged via a common effluent outfall into the Great Miami River. A Parshal-Flume-type water sampler collects samples of the combined effluent stream, which are removed and analyzed daily. These results are utilized with measurements of river flow in calculating the radioactive contaminant concentrations added to the river. Weekly spot samples are obtained upstream; downstream, a continuous sample is taken for a 24-hour period and at least one sample is analyzed each week. Samples of the storm sewer overflow are collected in an automatic flow integrated sampler when overflow occurs. All samples are analyzed for uranium, total radioactivity and radium-228, a daughter of thorium-232. Since radium-228 has the lowest AEC standard, control of this radionuclide and of the total radioactivity insures that the AEC standards for the thorium decay chain are not exceeded.

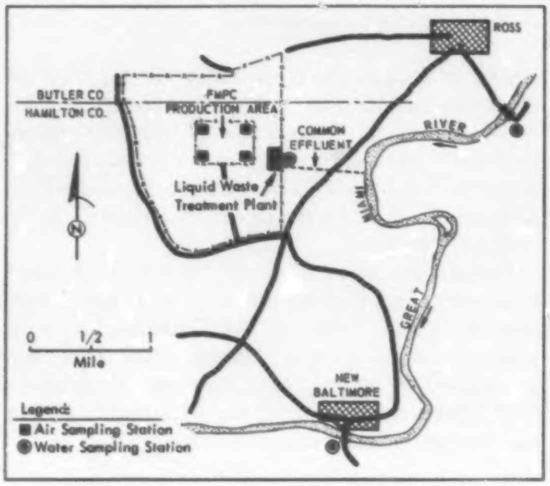

Figure 4. Air and water sampling stations, FMPC

The average concentrations of all sampled contaminants at the downstream position indicate each contaminant was well below the AEC standard. It may be concluded from sampling and calculations that the FMPC effluent produced little change in the river's quality. The results of the FMPC water monitoring program for July-December 1969 are summarized in table 8.

Table 7. Radioactivity levels of airborne particulates, FMPC, July–December 1969

Location	Number of samples	Uranium concentration[a] (pCi/m³)			Total radioactivity[b] (pCi/m³)		
		Maximum	Minimum	Average	Maximum	Minimum	Average
Onsite:							
Southwest	22	0.2	<0.1	<0.1	0.6	<0.1	0.2
Northwest	24	.1	< .1	< .1	1.1	< .1	.2
Northeast	24	.4	< .1	.1	.8	< .1	.2
Southeast	23	.2	< .1	.1	.5	< .1	.2
All onsite samples	93			.1			.2
Offsite:							
0–2 miles from FMPC	32	.3	< .1	.1	1.5	< .1	.3
2–4 miles from FMPC	35	< .1	< .1	< .1	.5	< .1	.2
4–8 miles from FMPC	39	.1	< .1	< .1	.6	< .1	.2
8–12 miles from FMPC	10	< .1	< .1	< .1	.7	< .1	.3
All offsite samples	116			.1			.2

[a] AEC radiation protection standard—2 pCi/m³.
[b] AEC radiation protection standard—100 pCi/m³. Total radioactivity is the sum of the alpha and beta radioactivity.

Table 8. Radioactivity in the Great Miami River, FMPC, July-December 1969

Location	Number of samples	Total radioactivity[a] (pCi/liter)			Concentration (pCi/liter)						
					Uranium[b]			Radium-228[c]			
		Maximum	Minimum	Average	Maximum	Minimum	Average	Number of samples	Maximum	Minimum	Average
Sewer outfall[d]	184	260	<10	10	<10	<10	<10	22	2.35	0.05	0.70
Upstream from outfall	28	490	<10	<10	90	<10	15	7	2.27	.45	1.09
Downstream from outfall	28	100	<10	<10	10	<10	3	7	2.27	.45	1.27

[a] AEC standard—3,000 pCi/liter. Total radioactivity is the sum of the alpha and beta radioactivity.
[b] AEC standard—20,000 pCi/liter.
[c] AEC standard—30 pCi/liter.
[d] Concentrations in the river as calculated from sewer outfall sample results.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1968	August 1969
January–June 1969	March 1970

3. Neutron Devices Department.[4]
July–December 1969

General Electric Company
St. Petersburg, Fla.

The Neutron Devices Department (figure 5) is an electronic component production facility. The plant maintains an environmental monitoring program to measure the levels of radioactive environmental contamination associated with plant effluents. These measurements serve as an index of the effectiveness of the plant's contamination control measures. Effluent radioactivity concentrations and associated atmospheric and stream dilution factors indicate offsite radioactivity concentrations encountered by the general population are substantially lower than the guides for continuous nonoccupational exposure established by AEC and documented in the "AEC Manual."

Sewer effluent monitoring

A combined sewer effluent sample is obtained

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[4] Summarized from "Environmental Monitoring, July 1 through December 1969" General Electric Company, Neutron Devices Department, St. Petersburg, Fla.

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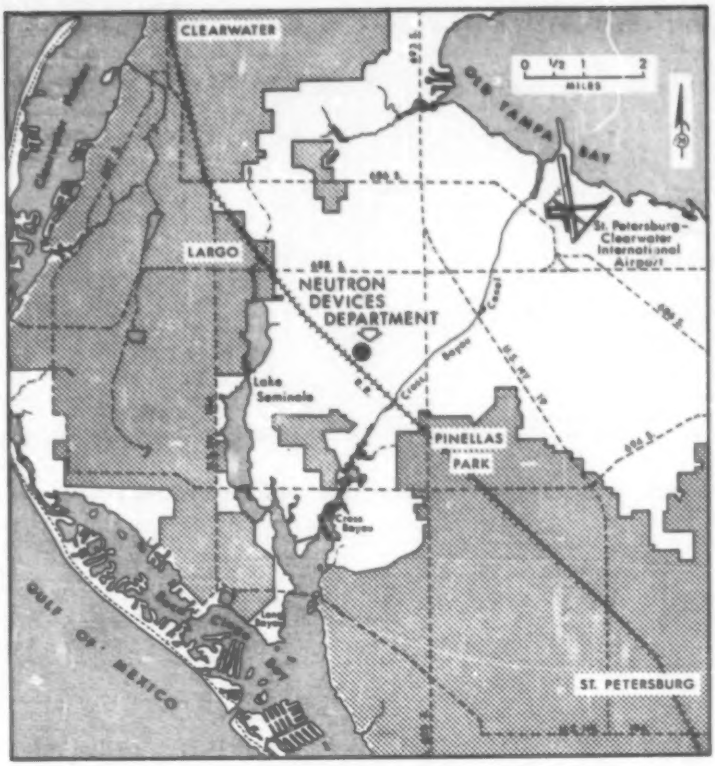
CLEARWATER
OLD TAMPA BAY
0 1/2 1 2
MILES
St. Petersburg-Clearwater International Airport
LARGO
NEUTRON DEVICES DEPARTMENT
Lake Seminole
Cross Bayou Canal
PINELLAS PARK
Cross Bayou
GULF OF MEXICO
ST. PETERSBURG

Figure 5. Location of the Neutron Devices Department

daily near the perimeter of the plant's property. During the sampling period seven of 104 samples analyzed showed detectable concentrations of tritium (>90 nCi/liter). The maximum concentration (1.27 μCi/liter, detected on August 28, 1969) represented 42 percent of the continuous nonoccupational exposure guide. Calculations based on radioactivity releases from the process waste system and the plant's water discharges indicate that the average tritium concentration in the combined sewer effluent for the second half of 1969 was less than 3.8 percent of the AEC standard for continuous nonoccupational exposure.

Surface water sampling

Surface water samples are collected at monthly intervals at selected locations within 8 miles of the plant. The sampling areas are determined by interrelating the concentrations of radioactivity in exhaust stack effluent with meteorological data. There were no indications of tritium (>90 nCi/liter) in the 115 surface water samples analyzed during the sampling period.

Milk sampling results

Analyses of 7 raw milk samples, collected from one local dairy farm by the Pinellas County Health Department, revealed no detectable concentrations (>90 nCi/liter) of tritium.

Air sampling results

Nine tritium gas and 11 tritium oxide in air samples were collected around the calculated locations of maximum ground level concentrations during intentional radioactivity releases. The maximum concentrations occurred onsite and represented approximately 33 percent and 17 percent of the AEC standards for tritium oxide and tritium gas, respectively.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1968	January 1970
January–June 1969	April 1970

Reported Nuclear Detonations, July 1970

(Includes seismic signals from foreign test areas)

The U.S. Atomic Commission announced that on July 20, 1970, the United States recorded seismic signals, presumably from a Soviet underground nuclear explosion. The signals, which originated in the Semipalatinsk nuclear test area, were equivalent to those of an underground nuclear explosion in the low-intermediate yield range (20–200 kilotons TNT equivalent).

On July 23, 1970, the United States recorded seismic signals, presumably from a Soviet underground nuclear explosion. The signals, which originated in the Semipalatinsk nuclear test area, were equivalent to those of an underground nuclear explosion in the low-intermediate yield range (20–200 kilotons TNT equivalent).

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

A PRIORITY SYSTEM FOR THE INSPECTION OF X-RAY FACILITIES. *Bobby L. Dillard* and *Charles M. Hardin. Radiological Health Data and Reports, Vol. 11, August 1970*, pp. 367–372.

A method of establishing a priority system for performing radiation safety inspections of specific x-ray facilities by a State radiation control program is described. Data obtained from past inspections of radiographic fluoroscopic and dental x-ray facilities are evaluated, and a priority number is assigned to these facilities. Those facilities with the highest priority number will be surveyed first on the next round of inspections.

KEYWORDS: Fluoroscopy, inspection, Kentucky, radiography, safety, survey, system, x-ray facilities.

DISPOSAL OF RADIOACTIVE WASTES FROM U.S. NAVAL NUCLEAR-POWERED SHIPS AND THEIR SUPPORT FACILITIES, 1969. *J. J. Mangeno* and *M. E. Miles. Radiological Health Data and Reports, Vol. 11, August 1970*, pp. 373–378.

This report summarizes data on disposal of radioactive wastes from U.S. Naval nuclear-powered ships and their support facilities and summarizes results of environmental monitoring performed to confirm adequacy of waste disposal limits and procedures. The waste disposal data presented show that the total long-lived radioactivity in liquid waste discharges associated with operation and maintenance of Naval nuclear-powered ships totaled 0.05 curies in 1969 for all harbors. This is comparable to the average of 0.2 curies discharged per year during the preceding 3 years for all harbors and is less than the average of 4 curies reported discharged per year during the preceding 5 years. Results of environmental surveys of harbor water and bottom sediment for gross radioactivity and for cobalt-60 have shown that (1) no increase in radioactivity above normal background levels has been detected in harbor water, (2) discharges of liquid wastes from U.S. Naval nuclear-powered ships have not caused a measurable increase in the general background radioactivity of the environment, and (3) low-level cobalt-60 radioactivity is detectable in localized areas of harbor bottom sediment around a few piers at operating bases and shipyards where maintenance and overhaul of Naval nuclear-powered ships have been conducted over a period of several years.

This report confirms that procedures used by the Navy to control discharges of radioactivity from U.S. Naval nuclear-powered ships and their support facilities are effective in protecting the health and safety of the general public.

KEYWORDS: Discharges, disposal, harbors, monitoring, nuclear-powered ships, radioactivity, U.S. Navy, wastes.

STANDBY MILK SURVEILLANCE NETWORK. *Thomas J. Sharpe* and *John L. Stein Radiological Health Data and Reports, Vol. 11, August 1970*, pp. 379–382.

The operation of the Standby Milk Surveillance Network of the Southwestern Radiological Health Laboratory is described. Portions of the network have been activated on several occasions. Fresh fission products have been defined in a number of samples collected from processing plants in the network, although in all cases the concentrations of the radionuclides present have been well below the recommendations of the Federal Radiation Council.

KEYWORDS: Milk, United States, iodine–131, surveillance network.

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RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 11, Number 9, September 1970

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the Bureau of Radiological Health, Public Health Service.

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
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Reports

Tritium in Streams in the United States, 1961-1968

T. A. Wyerman,[1] *R. K. Farnsworth,*[2] and *G. L. Stewart*[3]

As part of its program of water resources investigations, the U.S. Geological Survey has been analyzing the tritium content of stream water since the early 1960's. The results of this sampling program for 20 streams in the conterminous United States and Alaska are tabulated along with relevant stream discharge data. The data show the effect on stream tritium concentration caused principally by thermonuclear detonations, and also seasonal, latitudinal, and continental effects.

Before the first thermonuclear device was tested in 1952, tritium was very scarce in natural waters (*1–4*). Natural tritium is largely created by the bombardment of nitrogen in the upper atmosphere by nuclear particles in cosmic radiation. Subsequent oxidation of the tritium (T) leads to the tritiated water molecule (HTO) which eventually reaches the earth's surface in precipitation.

Because the rate of production of natural tritium in the atmosphere is believed to be relatively constant and the tritium decay rate of 5.5 percent (*5*) per year is constant, a worldwide equilibrium in tritium in the hydrologic cycle was in effect prior to 1952. Before hydrologic studies were set up to measure and utilize the distribution of natural tritium in the hydrologic cycle, the detonation of thermonuclear devices yielded large quantities of artificial tritium to the atmosphere and upset the equilibrium. Consequently, the hope for the hydrologic use of tritium shifted from a hydrologic cycle generally in equilibrium with natural tritium to one thrown out of equilibrium by large irregular input pulses of artificial tritium.

At the earth's surface, precipitation generally gives the first indication of artificial tritium input to the hydrologic cycle by thermonuclear explosions. There has been an irregular rise and fall in tritium concentration in precipitation due directly to thermonuclear explosions, especially in the Northern Hemisphere. For instance, at Chicago, the tritium concentration in precipitation increased from about 32 pCi/liter[4] before 1954, to a maximum of approximately 12,800 pCi/liter in 1963, and then declined to about 320 pCi/liter in 1968. Superimposed on this long-term rise and fall in tritium concentration are short seasonal and annual variations and latitude and continental effects (*6–7*). The effects of these variations of tritium in precipitation upon the tritium concentration of streams in the United States during 1961–1968 are the basis for this report.

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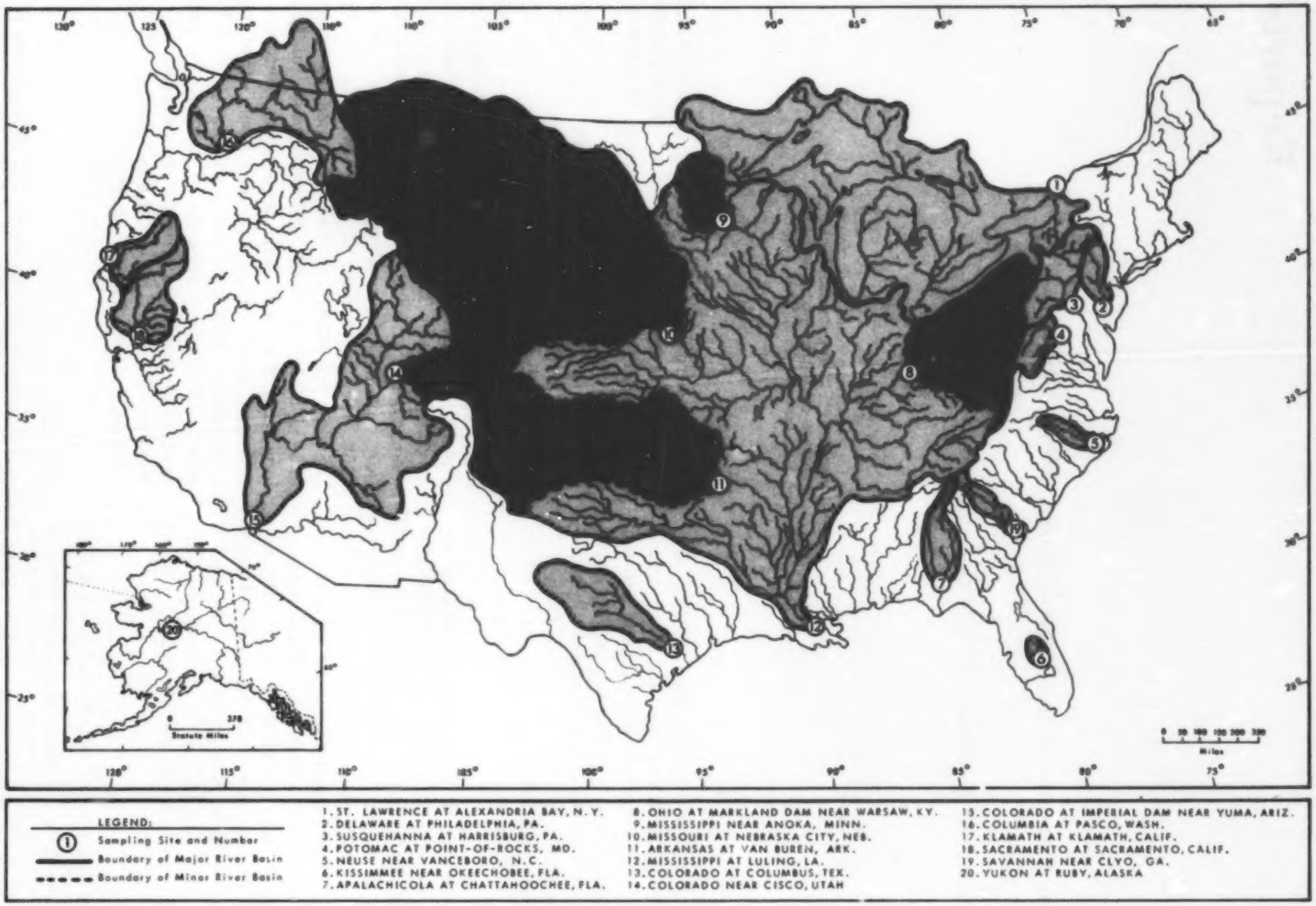
[3] Dr. Stewart is an assistant professor, College of Agriculture, University of Massachusetts, Amherst, Mass.

[4] One picocurie per liter equals 2.22 disintegrations per minute per liter and 0.3083 tritium units. One tritium unit is one tritium atom in 10^{18} hydrogen atoms.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LEGEND:
① Sampling Site and Number
Boundary of Major River Basin
Boundary of Minor River Basin
1. ST. LAWRENCE AT ALEXANDRIA BAY, N.Y.
2. DELAWARE AT PHILADELPHIA, PA.
3. SUSQUEHANNA AT HARRISBURG, PA.
4. POTOMAC AT POINT-OF-ROCKS, MD.
5. NEUSE NEAR VANCEBORO, N.C.
6. KISSIMMEE NEAR OKEECHOBEE, FLA.
7. APALACHICOLA AT CHATTAHOOCHEE, FLA.
8. OHIO AT MARKLAND DAM NEAR WARSAW, KY.
9. MISSISSIPPI NEAR ANOKA, MINN.
10. MISSOURI AT NEBRASKA CITY, NEB.
11. ARKANSAS AT VAN BUREN, ARK.
12. MISSISSIPPI AT LULING, LA.
13. COLORADO AT COLUMBUS, TEX.
14. COLORADO NEAR CISCO, UTAH
15. COLORADO AT IMPERIAL DAM NEAR YUMA, ARIZ.
16. COLUMBIA AT PASCO, WASH.
17. KLAMATH AT KLAMATH, CALIF.
18. SACRAMENTO AT SACRAMENTO, CALIF.
19. SAVANNAH NEAR CLYO, GA.
20. YUKON AT RUBY, ALASKA

Figure 1. Stream tritium sampling locations in continental United States

The network

In 1963, the U.S. Geological Survey began a routine sampling program on streams to determine the tritium concentration of surface water in the continental United States. Before 1963, stream sampling for this purpose was irregular. In 1964 and 1965, the sampling network was expanded to include eight more streams, but the station on one of these streams, the St. Lawrence River, was discontinued in 1967. The accompanying tables present the results of all analyses of network stream samples received in the tritium laboratory to the end of 1968. Figure 1 shows the basins and sampling locations of all the streams sampled, except for the Yukon River at Ruby, Alaska.

Sampling procedure

Stream samples of 50 to 1,000 milliliters were collected by personnel of the U.S. Geological Survey at or near gauging stations where stream discharge data are collected. Where a specific date of sampling is shown in the tables, the sample was a single grab sample collected on that date. Where a month only is shown, the sample consisted of a composite of daily, weekly, or biweekly grab samples collected during that month. The notation "NS" in the tables indicates that no sample was collected for the period listed; however, the period is included to permit continuity of the discharge record.

Analytical procedures

After samples were received at the laboratory, they were either subjected to tritium counts directly by one of two types of counting systems, or were enriched by electrolysis before counting. The analytical techniques described by Hoffman and Stewart (*8*), were generally applied to the earlier samples; however, improvements in systems and techniques have since been made and adapted to tritium analyses. Presently, if the tritium concentration exceeds about 1,000 pCi/liter, 5 milliliters of the samples are predistilled and counted without enrichment using a model 3003 Packard liquid scintillation spectrometer. The counting solution contains 4 milliliters of water emulsified in 18 milliliters of scintillation solution, which consists of 76 percent (by volume) toluene, 24 percent Triton X-100 (Rohm and Haas) (alkylaryl polyether alcohol), 7 grams per liter of PPO (2,5 diphenyloxazole), and 0.5 grams per liter of POPOP [1,4-bis-2-(phenyloxazolyl)-benzene]. This mixture in a 25-milliliter polyethylene vial yields a counting efficiency for tritium of about 27 percent and a background of about 7.5 counts per minute.

Table 1. Apalachicola River at Chattahoochee, Fla.

Date	Tritium concentration (pCi/liter)	Discharge (m^3/s)	
		Daily	Monthly mean
1964			
November 28	646	753	612
November 20	624	657	—
December 30	691	2,540	1,170
1965			
January 27	720	1,512	1,103
February 15	NS	1,736	1,484
March 3	570	1,535	1,436
April 12	608	1,379	1,111
May 6	576	680	489
June 9	592	564	745
July 12	544	606	574
July 27	534	504	—
August 15	NS	487	405
September 1	643	323	371
October 11	512	578	490
November 15	NS	326	370
December 3	685	484	454
1966			
January 14	544	909	947
February 25	358	1,996	636
March 14	470	1,755	2,058
April 1	416	1,079	680
May 3	429	572	786
June 3	614	833	594
July 5	483	354	383
August 1	525	362	456
August 29	566	394	—
September 15	NS	314	328
October 4	467	320	363
November 14	512	971	570
December 2	528	390	489
1967			
January 9	317	1,453	1,292
February 2	557	850	1,012
March 2	435	909	677
March 28	304	544	—
April 15	NS	365	404
May 8	288	385	380
June 6	320	450	452
July 21	422	776	584
August 14	390	351	464
September 20	355	456	521
October 3	352	334	352
November 7	358	600	472
December 14	378	997	846
1968			
January 15	326	994	843
February 20	381	430	484
March 15	394	2,135	858
March 22	422	1,042	—
April 15	NS	481	537
May 15	NS	337	379
June 14	336	348	339
July 11	323	320	318
August 18	336	309	304
September 15	NS	253	258
October 23	305	208	220
November 15	288	223	251
December 12	330	351	364

NS, no sample.

Table 2. Arkansas River at Van Buren, Ark.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily	Monthly mean
1961			
October 10	206	2,500	1,325
November	NS		2,128
December 5[a]	176	1,337	1,410
1962			
January	NS		774
February	NS		904
March 15[a]	534	365	827
April	NS		958
May	NS		307
June 27[a]	1,420	513	1,182
July	NS		522
August 31	928	167	327
September	NS		871
October	NS		910
November	NS		465
December	NS		433
1963			
January	NS		315
February	NS		190
March	NS		464
April	1,610		331
May	3,520		277
June	4,830		221
July	5,890		330
August	2,370		196
September	2,320		261
October	2,410		92
November	2,120		65
December	1,300		50
1964			
January	1,240		51
February	1,480		70
March	1,910		145
April	2,140		448
May	2,490		393
June	2,660		615
July	2,670		207
August	2,250		167
September	1,890		333
October	1,780		102
November	NS		778
December	1,220		508
1965			
January	1,410		373
February	1,290		298
March	1,540		414
April	1,290		1,656
May	1,100		600
June	1,180		1,381
July	1,280		780
August	1,240		292
September	1,080		921
October	1,100		448
November	800		130
December	966		151
1966			
January	845		246
February	781		600
March	794		334
April	906		524
May	733		723
June	794		372
July	797		228
August	1,206		318
September	858		204
October	806		179
November	906		145
December	778		118
1967			
January	794		82
February	820		68
March	749		71
April	733		378
May	528		419
June	1,240		588
July	582		1,307
August	698		458
September	582		415
October	621		549
November	579		694
December	474		387
1968			
January	483		526
February	438		1,180
March	490		1,583
April	406		1,735
May	390		1,664
June	464		1,303
July	394		560
August	426		644
September	352		338
October	394		334
November	320		876
December	311		1,329

[a] Sampled at Little Rock, Ark.
NS, no sample.

Samples believed to have tritium concentrations between 250 and 1,000 pCi/liter, are counted directly in a 2-liter gas proportional counter filled to 2 atmospheres of gas pressure with 80 percent hydrogen gas and 20 percent methane. About 2 to 2.5 milliliters of water are converted to hydrogen gas by passing the vapor over uranium metal heated to a temperature of 875° C. The gas proportional system yields a tritium counting efficiency of about 95 percent and background about 2.5 counts per minute.

Samples below 250 pCi/liter are enriched by electrolysis using a technique and electrolysis cells similar to those described by Ostlund and Weiner (*9*). In this procedure, 50, 100, 250, or 500 milliliters of a predistilled water sample are electrolytically reduced to 5 to 10 milliliters of tritium-enriched water containing about 75 to 90 percent of the initial tritium. After a final distillation to remove the neutralized electrolyte, the tritium-enriched sample is counted by one of the above-described systems, depending upon the anticipated final tritium concentration.

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Table 3. Colorado River near Cisco, Utah

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily	Monthly mean
1961			
September 21	419	133	150
October 9	490	270	164
1962			
August 14	1,400	93	95
1963			
January	NS		73
February	NS		99
March	3,120		101
April	2,040		116
May	4,480		238
June	5,090		158
July	4,450		53
August	3,580		77
September	3,120		87
October	NS		62
November	2,430		85
December	2,020		64
1964			
January	1,370		61
February	1,440		60
March	1,870		59
April	3,030		102
May	6,140		396
June	7,300		371
July	5,920		127
August	3,740		111
September	3,580		73
October	3,490		75
November	3,140		87
December	2,410		83
1965			
January	1,760		75
February	1,440		72
March	2,270		71
April	3,100		268
May	3,740		586
June	3,970		787
July	3,230		514
August	2,960		206
September	2,500		176
October	2,150		166
November	2,380		110
December	1,830		109
1966			
January	2,010		92
February	2,120		86
March	1,870		128
April	2,390		209
May	2,310		321
June	2,440		204
July	2,350		83
August	2,460		55
September	2,560		60
October	2,070		80
November	1,800		73
December	2,060		80
1967			
January	NS		67
February	1,550		69
March	1,850		85
April	NS		94
May	1,550		213
June	1,680		340
July	1,570		151
August	NS		81
September	1,530		84
October	1,500		80
November	1,580		100
December	1,470		111
1968			
January	NS		95
February	1,450		95
March	1,350		79
April	1,310		110
May	1,000		307
June	1,390		537
July	1,240		141
August	995		168
September	NS		76
October	1,380		[a]97
November	1,310		[a]120
December	1,230		[a]111

[a] Discharge subject to revision.
NS, no sample

Accuracy

The errors associated with the analytical results listed in the tables average less than ± 10 percent at 1 standard deviation. Some of the earlier analyses may have had a slightly higher average error, but errors in the more recent analyses are known to average less than ± 10 percent.

Discussion of data

Although a more detailed interpretation of the data will be included in a later publication, certain trends that are obvious from the data listed in the tables are discussed here. The large pulse of tritium from precipitation because of thermonuclear testings, as shown by Stewart and Hoffman (*10*), is reflected in all the streams. Also apparent are the seasonal, latitudinal, and continental effects noted in precipitation. The amount of ground water flow relative to runoff appears to affect the response of streams to tritium in precipitation falling in the basin. This might be expected since ground water response to tritium in precipitation is obviously much slower than runoff response. During the early part of the recorded period, most streams contained considerably lower concentrations of tritium than

Table 4. Colorado River at Columbus, Texas

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily	Monthly mean
1964			
December 1	611	6.7	8.8
1965			
January 5	392	6.5	36
February 12	416	274	132
March 8	370	21	18
April 13	352	26	33
May 11	580	148	243
June 9	1,170	246	217
July 9	832	78	69
August 5	835	43	40
September 13	746	47	42
October 21	560	54	27
November 18	544	78	81
December 20	294	253	110
1966			
January 25	339	30	42
February	NS	—	33
March 2	480	72	32
April 5	426	53	72
May 11	608	169	206
June 16	557	72	70
July 26	608	53	56
August 29	518	33	44
September	NS	—	36
October 4	448	23	19
November 7	640	22	22
December 13	352	6.1	6.2
1967			
January 17	208	5.8	5.8
February	NS	—	5.7
March 27	768	30	18
April	NS	—	47
May 1	502	61	72
June 6	570	60	61
July 13	560	45	38
August 15	480	50	57
September 18	336	37	81
October 24	175	22	36
November	NS	—	44
December	NS	—	16
1968			
January 22	125	1,133	239
January 25	194	308	—
February 15	330	181	187
March 12	300	224	170
April 16	271	200	220
May	NS	—	304
June	NS	—	327
July 2	254	191	115
August 1	303	63	59
September	NS	—	83
October	NS	—	[a] 21
November	NS	—	[a] 14
December 4	138	[a] 58	[a] 20
December 18	130	[a] 14	—

[a] Discharge subject to revision.
NS, no sample.

Table 5. Colorado River at Imperial Dam near Yuma, Ariz.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily[a]	Monthly mean[b]
1964			
October	NS	—	183
November 5	1,060	153	133
December	NS	—	130
1965			
January	NS	—	125
February 4	1,150	157	169
March 3	1,320	257	253
April 1	1,440	294	269
May 5	1,370	270	253
June 4	1,330	256	275
July 7	1,540	327	326
August 2	1,470	328	339
September 2	1,500	295	257
October 8	1,500	223	184
November 4	1,540	148	122
December 1	1,410	102	109
1966			
January 5	1,250	80	94
February [illegible]	1,780	99	170
March 2	2,190	219	238
April 6	2,340	324	296
May 3	2,470	256	265
June 2	2,450	287	303
July 5	2,240	337	336
August 8	2,530	347	338
September 1	2,430	304	253
October 3	2,540	201	180
November 3	2,210	154	126
December 2	2,330	133	145
1967			
January 9	2,270	180	139
February 6	2,320	157	188
March 6	2,470	242	273
April 6	2,540	287	266
May 4	2,450	255	253
June 1	2,420	278	283
July 5	2,800	309	310
August 2	2,430	332	310
September 7	2,130	150	214
October 5	2,110	221	190
November 7	1,790	160	128
December 5	1,810	79	80
1968			
January 8	2,140	130	158
February 6	2,080	176	180
March 5	2,050	238	261
April 2	2,210	317	296
May 7	2,120	238	245
June 4	2,010	264	276
July 2	2,010	294	288
August 6	1,930	263	280
September 3	1,860	247	235
October 1	1,810	223	184
November 5	1,740	172	142
December 3	1,650	145	140

[a] At All-American Canal Station 60.
[b] Sum of discharges of All-American Canal, Gila Gravity Main Canal and Colorado River at Imperial Dam.
NS, no sample.

was present in precipitation, whereas later, the concentration of tritium in streams often exceeded that in precipitation. Figure 2 presents an example of this trend.

The Missouri River at Nebraska City, Nebr., shows good agreement between the monthly composite, which consists of equal volumes of daily samples, and the monthly grab sample. This suggests that the response of the river to changes in the rate of tritium input is not abrupt, at least for periods of less than a month. The effect of the nuclear facilities at the Savannah River Plant is obvious when tritium data from the Savannah River are compared to those of other streams. Also

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Table 6. Columbia River at Pasco, Wash.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily	Monthly mean[a]
1961			
September 15	394	1,844	1,887
October 17	397	1,706	1,805
1962			
July 2	832	6,431	5,400
1963			
April	813		2,913
May	1,330		4,110
June	1,790		7,703
July	2,210		5,731
August	3,230		3,008
September	NS		2,015
October	3,840		1,811
November	3,020		1,679
December	5,540		1,781
1964			
January	4,800		1,698
February	2,980		2,127
March	2,140		1,890
April	1,730		1,855
May	1,540		4,723
June	2,880		11,063
July	3,970		8,404
August	3,870		3,772
September	4,540		2,184
October	4,130		2,585
November	3,780		2,073
December	3,490		2,086
1965			
January	3,510		2,360
February	2,810		3,146
March	2,430		2,788
April	1,920		3,380
May	2,080		6,871
June	2,220		9,048
July	2,830		6,274
August	2,610		3,722
September	2,800		2,274
October	2,640		1,894
November	2,670		2,050
December	2,570		2,170
1966			
January	2,600		1,990
February	2,240		2,355
March	2,050		2,283
April	1,930		2,271
May	1,820		5,276
June	1,820		7,812
July	2,000		6,496
August	2,510		3,170
September	2,000		2,135
October	2,070		1,946
November	1,950		1,916
December	1,800		2,192
1967			
January	1,850		2,237
February	1,890		2,281
March	1,620		2,613
April 24	1,540	3,237	2,620
May 31	1,780	8,242	4,069
June 15	1,790	13,480	12,438
July 28	1,840	5,787	8,211
August 29	1,500	3,648	3,612
September 29	1,440	3,045	2,369
October 31	1,280	1,978	2,141
November 29	1,240	2,759	2,232
December 29	1,370	3,661	2,646
1968			
January 30	1,350	3,087	2,382
February 28	1,300	1,962	2,334
March 25	1,200	3,822	3,326
April	NS		2,889
May 1	1,230	3,048	3,647
June 1	1,170	5,182	7,746
July	NS		6,450
August	NS		3,284
September 3	1,130	2,818	2,646
September 25	1,120	3,062	—
October	NS		2,271
November 5	1,040	2,302	
November 27	1,220	3,418	
December 20	1,270	3,115	

[a] Discharge at Columbia River at Priest Rapids and Yakima River at Kiona, Wash.
NS, no sample.

obvious is the moderating effect of the Great Lakes on the tritium in the St. Lawrence River.

The Colorado River at Cisco, Utah, and most of the other sampled rivers reached their maximum tritium levels in 1963–1964, whereas the Colorado River near Yuma, Ariz., did not reach its highest level until 1966–1967. About a year after the maximum tritium concentration was reached in the Mississippi River, the concentration in the river at Luling, La., began to approximate about half the concentration near Anoka, Minn. The Yukon River carried the highest concentration derived from precipitation, whereas the Kissimee River had the lowest. Although their basins adjoin, the Potomac River had tritium levels significantly lower than the Ohio River.

REFERENCES

(1) LIBBY, W. F. The potential usefulness of natural tritium. Natl Acad Sci Proc 39:245 (1953).

(2) LIBBY, W. F. Tritium in nature. J Washington Acad Sci 45:301 (1955).

(3) KAUFMAN, S. and W. F. LIBBY. The natural distribution of tritium. Phys Rev 93:1337–1344 (1954).

(4) VON BUTTLAR, H. and W. F. LIBBY. Natural distribution of cosmic-ray produced tritium, II. J Inorg Nucl Chem 1:75–91 (1955).

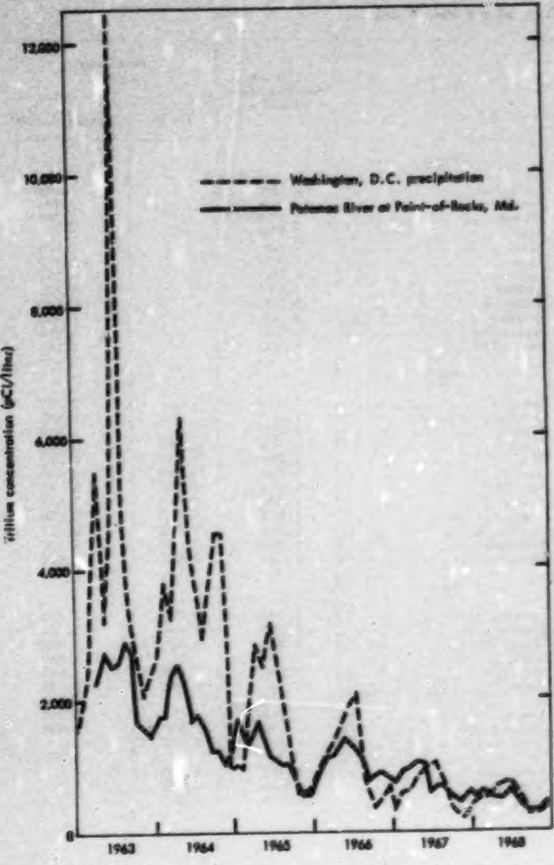

Figure 2. Tritium concentration in Washington, D.C. precipitation and in the Potomac River at Point-of-Rocks, Md.

Table 7. Delaware River at Philadelphia, Pa.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily[a]	Monthly mean[a]
1964			
October 22	2,000	55	61
November 17	1,830	44	54
December 17	1,080	101	111
1965			
January 5	1,410	119	140
February 15	1,340	433	343
March 15	1,310	235	256
April 13	1,250	334	278
May 17	1,570	125	148
May 28	1,450	98	—
June 14	1,380	62	73
July 15	1,480	49	44
August 16	1,560	50	51
September 13	1,380	62	39
October 19	1,180	103	98
November	NS		75
December	NS		143
1966			
January	NS		143
February	NS		250
March 16	1,220	453	502
April 14	1,180	187	220
May 23	1,200	277	301
June 20	1,100	130	176
July	NS		72
August	NS		70
September	NS		77
October	NS		103
November	NS		129
December 7	900	163	199
1967			
January 6	750	196	286
February	NS		246
March 8	840	507	523
April 13	830	411	516
May 4	800	300	426
June 12	830	125	176
July 14	820	221	150
August 3	860	304	286
September	NS		135
October 5	690	114	142
November 9	630	317	252
December	NS		416
1968			
January	NS		193
February	NS		278
March	NS		471
April	NS		334
May	NS		440
June	NS		575
July 10	630	186	201
August 8	610	144	124
September 5	570	114	134
October 1	560	107	124
November 21	540	742	275
December 5	520	515	296

[a] Discharge at Trenton, N.J.
NS, no sample.

REFERENCES—Continued

(5) JONES, W. M. Half-life of tritium. Phys Rev 100: 124–235 (1955).

(6) STEWART, G. L. and R. K. FARNSWORTH. United States tritium rainout and its hydrologic implications. Water Resources Res 4:273–289 (1968).

(7) STEWART, G. L. and T. A. WYERMAN. Tritium rainout in the United States during 1966, 1967, and 1968. Water Resources Res. 6:77–87 (1970).

(8) HOFFMAN, C. M. and G. L. STEWART. Quantitative Determination of Tritium in Natural Waters, Water Supply Paper 1696-D. U. S. Geological Survey (1966).

(9) OSTLUND, H. G., and E. WEINER. The Electrolytic Enrichment of Tritium and Deuterium for Natural Tritium Measurements, Tritium in the Physical and Biological Sciences Symposium Proceedings 1:95–105 (1962), International Atomic Energy Agency, Vienna, May 3–10, 1961.

(10) STEWART, G. L. and C. F. HOFFMAN. Tritium rainout over the United States in 1962 and 1963. U.S. Geological Survey Circular 520 (1966).

Table 8. Kissimmee River near Okeechobee, Fla.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily[a]	Monthly mean[a]
1961			
October 17	83.2	13	13
1962			
August 9	370	21	35
September	NS		80
October	NS		38
November	NS		14
December	NS		9
1963			
January	NS		8
February	NS		12
March	NS		24
April	1,030		14
May	1,130		11
June	2,210		15
July	2,030		16
August	NS		13
September	2,240		17
October	1,300		21
November	1,340		16
December	1,250		18
1964			
January	1,120		23
February	1,250		58
March	NS		67
April	NS		44
May	NS		45
June	1,110		37
July	NS		17
August	800		27
September	NS		67
October	NS		72
November	838		24
December	720		11
1965			
January	720		21
February	NS		27
March	650		48
April	370		32
May	636		13
June	618		11
July	698		29
August	341		33
September	433		36
October	291		38
November	336		46
December	NS		19
1966			
January	378		29
February	289		62
March	304		113
April	298		82
May	358		50
June	366		34
July	340		36
August	397		94
September	288		76
October	307		78
November	378		26
December	381		7
1967			
January	378		6
February	NS		7
March	332		5
April	307		3
May	384		11
June	304		14
July	271		15
August	214		48
September	230		69
October	215		47
November	194		7
December	168		7
1968			
January	180		6
February	178		6
March	130		5
April	222		3
May	101		6
June	141		100
July	127		191
August	158		106
September	137		84
October	134		64
November	88.6		22
December	104		10

NS, no sample.

Table 9. Mississippi River near Anoka, Minn.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily	Monthly mean
1961			
September 19	315	50	52
October 13	276	82	67
1962			
July 3	947	271	340
1963			
January	NS		103
February	NS		90
March	NS		157
April	1,980		301
May	4,060		287
June	5,800		432
July	4,420		120
August	6,240		135
September	4,480		113
October	3,460		82
November	3,420		81
December	2,620		70
1964			
January	2,430		74
February	2,320		74
March 23	2,370	114	92
April	NS		324
May	NS		450
June	NS		156
July 10	5,280	131	134
August 4	4,640	103	78
September 25	4,160	320	243
October 13	3,420	153	154
November 5	3,330	122	115
December 3	3,170	92	97
1965			
January 12	3,010	93	94
February 8	3,070	86	88
March 29	2,720	88	91
April 23	3,900	1,676	1,175
May 29	3,490	813	778
June 3	2,910	765	777
July 10	3,200	283	230
August 11	3,170	184	162
August 18	3,180	155	—
September	NS		210
1965			
October 6	2,300	651	515
November 29	2,510	105	276
December 10	2,540	242	249
1966			
January 12	2,310	204	200
February 16	1,800	411	282
March 25	2,130	1,005	663
April 22	2,440	787	790
May 20	2,480	623	657
June 21	2,450	220	316
July 18	2,360	234	232
August 9	2,280	190	253
August 23	2,550	326	—
September 20	2,410	165	187
October 10	2,030	149	165
November 7	1,850	145	156
December 7	2,030	130	125
1967			
January 4	1,930	125	132
February 8	1,920	138	130
March	NS		191
April 5	1,110	1,150	740
April 26	1,550	538	—
May 17	1,620	331	338
June 12	1,600	257	365
July 18	1,700	171	206
August 10	1,630	102	95
September 20	1,500	87	75
October	NS		
November 20	1,450	90	78
December 14	1,240	71	74
1968			
January 23	1,210	72	67
February 20	1,240	58	68
March 25	1,220	186	134
April 15	900	232	247
May 21	1,170	254	263
June 21	1,100	498	400
July	NS		298
August 1	1,160	193	122
September 4	1,220	83	123
October 1	1,000	227	368
November 12	1,080	286	296
December 12	900	198	163

NS, no sample.

1.08

Table 10. Mississippi River at Luling-to-Destrahan Ferry, La.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily[a]	Monthly mean[b]
1962			
September 17	278	8,212	10,030
October 20	224	9,514	11,320
1962			
January 8	358	17,920	21,090
March 6	371	30,700	34,120
July 30	1,450	10,650	10,020
1963			
January	NS		9,577
February	NS		8,614
March	NS		19,420
April	2,910		22,590
May	2,890		9,783
June	4,540		8,696
July	3,740		6,080
August	3,200		5,380
September	3,080		4,344
October	3,230		3,633
November	2,560		3,823
December	2,270		4,616
1964			
January	2,110		5,182
February	2,050		7,192
March	2,110		17,240
April	2,420		23,810
May	2,430		22,820
June	2,980		9,543
July	2,880		8,207
August	2,670		4,814
September	2,470		4,814
October	2,220		5,493
November	2,240		4,842
December	1,500		10,250
1965			
January	1,200		12,090
February	1,220		14,920
March	1,310		17,780
April	1,620		23,640
May	2,080		17,900
June	2,140		11,040
July	2,150		8,750
August	1,740		5,890
1965			
September	1,800		7,192
October	1,140		10,137
November	1,370		6,116
December	1,470		6,230
1966			
January	1,070		11,628
February	877		17,556
March	832		19,037
April	1,140		10,364
May	1,070		20,954
June	1,310		11,100
July	1,400		5,862
August	1,600		5,220
September	1,330		4,842
October	1,280		4,701
November	NS		[a]7,373
December	1,220		9,316
1967			
January	736		8,155
February	992		7,937
March	800		13,080
April	1,040		14,190
May	864		17,730
June 20	864	12,800	14,410
June 28, 29, 30	835	18,040	—
July	682		13,480
August	816		8,130
September	867		5,663
October	922		6,088
November	NS		8,070
December	NS		13,640
1968			
January	442		17,471
February	506		16,820
March	347		11,638
April	373		22,427
May	331		15,461
June	544		18,717
July	682		8,523
August	755		7,815
September	784		5,125
October	701		5,578
November	NS		6,730
December	NS		11,157

[a] Discharge at Vicksburg, Miss.
[b] Discharge at Tarbert Landing, Miss.
NS, no sample.

Table 11. Missouri River at Nebraska City, Nebr.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily	Monthly mean
1963			
April	3,620		949
May	4,960		943
June	7,810		1,113
July	4,670		942
August	3,420		950
September	2,940		936
October	3,970		928
November	3,160		899
December	2,700		311
1964			
January	2,020		343
February	1,980		408
March	2,130		545
April	2,940		974
May	3,870		1,067
June	3,870		1,261
July	4,030		969
August	4,540		1,026
September	4,030		984
October	4,480		954
November 16	4,420	1,002	
November	4,220		940
December 21	2,590	425	
December	3,390		390
1965			
January 19	2,700	285	
January	2,750		392
February	2,400		454
March 12	2,850	966	
March	2,720		896
April 21	3,070	1,014	
April	3,010		1,547
May 28	2,860	1,920	
May	3,490		1,285
June	3,190		1,273
July 9	4,000	1,232	
July	3,710		1,140
August 10	5,120	1,022	
August	4,190		[illegible]
September 13	3,550	1,156	
September	3,200		1,279
October 18	3,580	1,096	
October	3,330		1,201
November 23	3,490	1,124	
November	3,550		1,075
December 8	2,830	733	
December	2,900		727
1966			
January 20	2,970	578	
January	3,050		606
February 9	3,390	1,356	
February	2,150		949
March 3	2,300	923	
March	2,270		902
April 3	2,830	1,133	
April	3,050		1,067
May 17	3,650	1,008	
May	3,360		1,013
June 15	3,780	1,033	
June	3,360		1,105
July 20	3,530	1,008	
July	3,810		1,049
August 4	3,400	1,053	
August	3,520		1,126
September 16	3,300	1,019	
September	3,560		1,012
October 13	3,840	974	
October	3,100		1,028
November 4	3,420	1,036	
November	3,170		1,005
December 13	2,750	510	
December	2,060		498
1967			
January 27	2,180	410	
January	2,530		387
February 16	2,500	481	
February	2,070		433
March 6	2,080	994	
March	1,650		735
April 19	2,970	1,002	
April	2,820		1,033
May 12	2,690	1,158	
May	2,690		1,036
June 26	1,580	2,044	
June	1,570		2,321
July 27	2,400	1,235	
July	2,340		1,192
August 22	2,720	1,090	
August	2,440		1,102
September 20	2,450	1,099	
September	2,630		1,065
October 11	2,130	1,065	
October	2,250		1,083
November 21	2,040	1,042	
November	2,150		1,027
December 13	1,950	651	
December	1,910		594
1968			
January 9	2,250	311	
January	1,830		438
February 14	1,810	719	
February	1,600		694
March 26	1,860	1,036	
March	1,710		820
April 18	2,140	1,065	
April	2,050		1,080
May 16	2,040	1,082	
May	1,860		1,050
June 21	1,900	1,014	
June	1,860		1,117
July 24	1,800	1,201	
July	1,810		1,062
August 28	1,970	1,073	
August	1,880		1,048
September 24	1,780	966	
September	1,900		994
October 16	1,780	1,011	
October	1,730		1,122
November 13	1,620	1,073	
Novembr	1,810		1,086
December 11	1,730	566	
December	1,570		636

Table 12. Neuse River near Vanceboro, N.C.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily[a]	Monthly mean[a]
1961			
October 19	191	13	15
November 1	192	12[b]	17
December	NS		52
1962			
January	NS		144
February	NS		130
March 19	640	232	195
August 2	1,240	41	51
September	NS		25
October	NS		22
November	NS		125
December	NS		75
1963			
January	NS		164
February	NS		150
March	NS		198
April	1,950		68
May	1,700		47
June	2,080		35
July	3,330		24
August	4,190		28
September	2,980		29
October	3,390		17
November	1,920		67
December	1,310		96
1964			
January	992		155
February	1,600		190
March	1,790		188
April	1,270		145
May	1,230		35
June	1,800		23
July	2,270		21
August	1,680		31
September	1,290		113
October	1,000		408
November	1,060		71
December	816		108
1965			
January	864		185
February	813		270
March	752		256
April	826		107
May	1,110		81
June	957		220
July	1,270		322
August	NS		222
September	1,340		40
October	922		24
November	357		20
December	379		20
1966			
January	576		30
February	672		146
March	685		232
April	784		45
May June	701		106 62
July August	771		18 31
September	784		17
October	630		15
November	646		16
December	752		28
1967			
January	768		80
February	302		100
March	315		75
April	432		33
May	448		40
June	512		50
July	544		55
August	534		80
September	422		81
October	NS		27
November	NS		26
December	NS		87
1968			
January	NS		190
February	NS		57
March 19	403	135	98
April 1	419	55	49
May 2	451	29	23
June 1	384	37	47
July 3	515	13	30
August	NS		11
September 5	387	6	6
October 5	358	4	11
November 5	304	8	26
December 5	298	24	29

[a] Discharge at Kinston, N.C.
[b] Instantaneous discharge.
NS, no sample.

Table 13. Ohio River at Markland Dam near Warsaw, Ky.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily[a]	Monthly mean[a]
1961			
September 18	480	456	464
October 19	352	413	663
1962			
August 17	1,470	394	456
1963			
January	NS		2,537
February	NS		2,248
March	NS		12,260
April	3,040		3,483
May	2,770		1,472
June	3,140		1,529
July	3,740		481
August	4,860		481
September	4,800		311
October	3,710		193
November	3,520		430
December	2,210		821
1964			
January	2,570		2,180
February	3,060		2,124
March	3,010		10,900
April	NS		6,456
May	3,090		2,152
June	2,930		910
July	3,810		481
August	NS		453
September	NS		261
October	NS		578
November 17	2,210	255	637
December 15	2,020	5,069	2,860
1965			
January 12	2,380	5,380	4,729
February 16	2,000	7,306	4,729
March 16	1,780	4,078	6,173
April	NS		7,249
May 18	1,960	1,215	1,926
June 2	1,610	844	643
June 18	1,640	527	—
July 16	1,700	614	572
August 17	2,220	255	331
September 24	1,420	348	957
October 22	1,390	1,260	975
November 18	1,200	1,309	1,015
December 19	1,330	1,133	1,072
1966			
January 18	1,120	1,283	2,775
January 21	1,130	909	2,765
February 18	1,220	14,080	6,080
March 18	1,000	2,975	2,972
April 16	1,370	5,935	3,449
May 27	1,190	1,426	[illegible]
June 24	1,170	694	625
July 22	1,240	378	561
August 18	1,320	1,014	602
September 22	1,170	966	619
October 20	1,190	422	926
November 30	1,110	2,107	1,642
December 21	1,170	2,333	3,993
1967			
January 20	1,220	1,133	1,801
February 20	1,030	2,701	2,945
March 23	816	10,730	9,911
April 24	804	4,389	4,332
May 15	688	10,020	7,419
May 17	688	11,520	—
June 16	832	872	1,138
July 25	896	668	883
August 17	778	408	793
September 18	720	303	541
October 16	787	722	1,220
November 14	749	1,121	1,614
December 19	580	2,818	3,710
1968			
January 16	618	1,594	2,549
February 21	630	1,051	3,908
March 18	500	7,617	5,239
April 22	762	1,623	3,936
May 8	598	1,294	5,063
June 10	669	2,362	3,964
July 23	723	917	838
August 12	646	3,313	1,337
September 17	630	750	490
October 21	746	1,031	617
November 13	602	1,067	1,506
December 11	650	2,308	2,602

[a] Discharge at Louisville, Ky. minus Kentucky River at Lockport, Ky.
NS, no sample.

Table 14. Potomac River at Point-of-Rocks, Md.

Date	Tritium concentration (pCi/liter)	Discharge (m^3/s)	
		Daily	Monthly mean
1961			
November 3	272	56	72
December 10	320	57	180
1962			
June 5	1,020	161	163
1963			
January	NS		246
February	NS		126
March	NS		1,091
April	2,240		209
May	2,720		126
June	2,500		166
July	2,560		55
August	2,900		37
September	2,750		35
October	1,630		28
November	1,540		72
December	1,440		107
1964			
January	1,730		437
February	1,730		281
March	2,400		738
April	2,530		445
May	2,300		361
June	1,660		78
July	1,750		61
August	1,590		39
September	1,190		30
October	1,220		67
November	990		63
December	1,280		151
1965			
January	1,720		383
February	1,360		457
March	1,330		677
April 1–14	1,610	[a] 423	—
April	1,660		419
May	1,390		202
June	1,090		66
July	1,040		42
August	1,020		33
September	1,000		34

Date	Tritium concentration (pCi/liter)	Discharge (m^3/s)	
		Daily	Monthly mean
1965			
October	640		43
November	541		33
December	534		35
1966			
January	NS		54
February 14–28	1,040	[a] 530	320
March	1,120		298
April	1,140		302
May 1–10	1,390	[a] 673	341
June	NS		98
July 8–31	1,280	[a] 28	30
August	1,060		26
September	774		115
October	848		165
November	896		105
December	797		195
1967			
January	723		221
February	912		256
March 1–24	989	[a] 1,000	880
March 25–31	1,090	[a] 511	—
April	1,040		220
May	1,020		436
June	566		126
July	672		124
August	675		149
September 1–24	563	[a] 74	75
October	NS		153
November	451		112
December	605		441
1968			
January 1–23	522	[a] 243	320
February	605		413
March	560		614
April	515		212
May	493		332
June 1–25	630	[a] 288	261
July	NS		66
August	362		51
September 1–14	306		40
October	320		[b] 43
November	336		[b] 137
December	426		[b] 98

[a] Mean discharge for period.
[b] Discharge subject to revision.
NS, no sample.

Table 15. Sacramento River at Sacramento, Calif.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily	Monthly mean
1961			
September 13[a]	144	294	274
October 24[a]	96	197	201
December 12	240	340	444
1962			
March 21	477	807	1,070
August 14	384	343	327
1963			
January	NS		546
February	NS		1,588
March	NS		692
April[a]	1,790		1,745
May[a]	1,500		1,211
June[a]	1,120		498
July[a]	1,600		344
August[a]	1,290		325
September[a]	608		459
October[a]	813		401
November	NS		641
December	NS		504
1964			
January	NS		700
February[a]	704		501
March[a]	672		407
April[a]	864		354
May[a]	813		395
June[a]	928		314
July	NS		329
August[a]	806		344
September[a]	928		375
October 22	1,000	246	275
October[a]	806		—
November[a]	1,060		393
December 1	976	447	1,035
December[a]	864		—
1965			
January 5	960	2,410	2,033
January[a]	864		—
February 3	717	1,730	1,302
February[a]	675		—
March 2	928	835	653
March[a]	870		—
April 1	915	648	1,194
May 5	851	900	852
June 4	979	586	454
July 9	1,010	328	344
August 5	880	371	409
September 23	800	473	439
October 19	736	405	395
November 3	723	405	571
December 21	544	614	640
1966			
January 20	464	866	978
February 11	502	926	765
March 9	474	479	671
April 14	636	810	615
May	NS		408
June 2	630	263	271
July 11	646	314	328
July 21	525	302	—
August 25	576	317	348
September 27	589	281	310
October	NS		239
November 6	704	326	327
December	422		1,314
1967			
January 18	458	436	1,022
February 28	406	799	1,463
March 29	422	1,229	1,184
April 11	336	1,458	1,420
April 25	358	1,008	—
May 29	368	1,739	1,470
June 16	400	1,229	1,218
July 28	384	447	532
August 25	416	430	426
September 29	400	481	526
1968			
July 22	320	345	357
December 12	217	640	630

[a] Sampled at Red Bluff, Calif.
NS, no sample.

Table 16. Klamath River near Klamath, Calif.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily	Monthly mean
1964			
October 20	842	97	83
November	NS		244
December 1	1,020	1,671	2,485
1965			
January	NS		1,732
February 25	704	643	893
March 24	896	453	525
April 30	1,000	685	611
May	NS		433
June 9	886	317	273
July 15	717	103	108
August 26	678	116	83
September	NS		95
October 6[a]	768	116	122
November 21	831	362	272
December	NS		287
1966			
January 8	845	1,835	949
February 3	586	481	467
February 25	496	450	—
March 30[a]	595	1,025	823
April 26	602	640	820
May	NS		485
June	NS		212
July	NS		102
August	NS		73
September 20	490	77	75
October	NS		88
November 2	456	90	283
November 28	442	253	—
December	NS		822
1967			
January 3	586	234	841
February 8	576	878	805
March 6	512	379	660
April	NS		562
May 22	515	1,141	832
June	NS		451
July 25	560	93	133
August 30	314	74	78
September	NS		76
October	NS		111
November 9	368	123	185
December 14	265	234	308
1968			
January 13	255	3,256	662
February	NS		1,237
March 11	340	561	690
April 1	300	540	380
May 1	316	306	251
June 4	319	187	142
July 16	330	81	82
August 21	264	79	73
September	NS		71
October 2	260	63	101
November	NS		344
December	NS		720

[a] Sampled at Del Norte, Calif.
NS, no sample.

Table 17. Savannah River near Clyo, Ga.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily	Monthly mean
1963			
May 1	1,500	234	468
1964			
October 23	7,870		500
November	NS		474
December 1	6,300	301	510
December 29	9,020	634	—
1965			
January			698
February 1	11,170	507	491
March 2	5,280	555	631
April 1	11,270	943	787
April 3	10,270	1,048	—
May 28	7,620	260	398
June	NS		379
July 1	4,260	648	374
August 2	17,500	379	357
September 1	32,320	252	274
October 1	6,370	242	251
December 1	9,950	243	246
1966			
January 4	27,740	248	336
February 2	10,340	348	404
March 1	14,270	663	953
March 31	9,760	671	—
April 26[a]	260	270	330
May 2	10,620	297	370
June 1	4,190	510	390
July 1	10,240	270	257
August 3	15,940	225	248
September	6,340	229	226
October	NS		217
November	NS		217
December	NS		228
1967			
January	NS		355
February	NS		313
March	NS		308
April	NS		238
May 25	5,630	294	253
June 7	9,470	265	453
June 15	4,260	462	—
July	NS		344
August 16	16,540	271	271
September 25	5,500	216	345
October 3	5,090	230	217
November 20	4,770	218	251
December 12	3,520	419	443
1968			
January 18	6,180	654	676
February 15	6,720	262	362
March 18	9,380	297	263
April 15	14,620	254	258
May 20	17,150	262	253
June 17	7,710	419	309
July 12	6,530	261	238
August 15	6,110	234	229
September 17	7,710	212	214
October 15	13,150	212	216
November 13	7,580	237	232
December 16	7,710	231	230

[a] Sampled at Aiken, S.C.
NS, no sample.

Table 18. St. Lawrence River at Alexandria Bay, N.Y.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily[a]	Monthly mean[a]
1964			
October 20	704	5,748	5,805
November 27	640	5,522	5,663
December 23	528	5,097	5,465
1965			
January 25	592	5,465	5,182
February 23	608	5,380	5,154
March 26	576	4,502	5,097
April 25	624	4,814	5,210
May 26	880	4,955	4,984
June 26	704	5,522	5,352
July 25	800	5,748	5,692
August 26	928	5,918	5,833
September 20	835	5,522	5,748
October 25	778	5,947	5,748
November 26	701	5,947	5,947
December 22	771	6,796	6,428
1966			
January 23	672	5,748	6,286
February 27	723	5,805	6,286
March 20	675	6,116	6,626
April 26	694	6,513	6,626
May 25	752	5,805	6,003
June 6	848	5,890	6,003
June 23	787	6,145	—
July 24	707	6,230	6,201
August 22	694	6,230	6,230
September 21	685	6,258	6,258
October 22	694	6,116	6,116
November 21	634	5,890	6,003
December 22	691	6,541	6,145
1967			
January 23	701	6,428	6,201
February 23	864	6,654	6,456
March 26	640	5,239	6,088
April 24	672	6,286	6,003
May 27	688	6,286	6,201
June 26	826	6,031	6,173
July 26	784	6,343	6,400
August 25	579	6,683	6,598
September 25	605	6,456	6,570
October 25	547	7,419	7,051
November 26	576	8,070	7,844
December 22	659	7,872	7,957

[a] Discharge at Ogdensburg, N.Y.

Table 19. Susquehanna River at Harrisburg, Pa.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily	Monthly mean
1960			
November 9	160	303	276
1961			
September 18	336	145	183
October 18	384	97	98
November 7	206	118	228
1962			
March 20	912	1,481	2,193
April 15	1,090	3,568	3,044
May	NS		642
June 20	1,120	220	206
June 28	928	155	208

Table 19. Susquehanna River at Harrisburg, Pa. —Continued

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily	Monthly mean
1964			
October 19	1,210	82	71
November 20	1,180	57	73
December 16	1,340	309	210
1965			
January	NS		473
February 16	2,050	2,010	1,156
March 15	2,050	937	1,038
April 15	2,080	1,603	1,512
May 17	2,110	654	720
May 26	1,890	388	720
June 16	1,810	186	243
July 14	1,700	105	94
August 18	1,760	97	100
September 15	1,680	97	114
October 15	1,500	300	200
November 16	1,610	265	303
December 15	1,580	357	424
1966			
January	NS		487
February 18	1,280	3,228	1,392
March 15	1,300	2,509	2,079
April 28	1,450	1,889	938
May 16	1,370	2,209	1,522
June 16	1,430	487	431
July 11	1,440	121	113
August 31	1,240	70	93
September 15	1,050	178	124
October 14	1,140	129	147
November 15	1,200	447	321
December 15	1,100	1,220	797
1967			
January 26	915	433	531
February 23	928	685	785
March 24	992	1,424	2,210
April 26	1,070	1,116	1,707
May 17	908	2,860	1,800
May 24	960	1,359	1,800
June 19	922	538	486
July 17	1,180	428	376
August 29	902	626	504
September 28	730	178	272
October 31	797	1,167	749
November 29	794	1,328	1,207
December 20	854	1,243	1,228
1968			
January	NS		470
February	NS		1,038
March 11	784	362	1,563
April 30	746	569	895
May 27	806	1,608	1,303
June	NS		1,420
July 3	691	1,009	472
July 24	608	223	472
August 23	611	138	152
September 26	531	165	330
October 25	586	195	172
November	NS		1,193
December 19	672	566	888

NS, no sample.

Table 20. Yukon River at Ruby, Alaska

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily	Monthly mean
1961			
September 17	740	6,400	7,180
October 13	610	[a] 1,700	[a] 5,120
December 12	510	[a] 1,610	[a] 1,610
1962			
January 31	2,500	[a] 1,420	[a] 1,420
May 31	1,570	21,200	[a] 7,470
July 16	1,530	3,340	13,870
July 31	1,490	12,800	—
September 21	900	8,440	10,480
1963			
June	6,020		13,040
July	6,750		13,490
August	7,710		12,810
1964			
June	7,840		24,500
July	8,580		15,530
August	8,130		10,600
September	4,580		7,750
October	4,100		[a] 4,240
1965			
August 10	4,580	11,350	9,700
August 28	3,200	8,440	
1966			
July 8	2,680		
August 1–16	2,140		
1968			
June 3–17	1,200		
June 18–July 17	1,440		
July 18–August 16	1,310		
August 18	1,380		
August 18–September 1	1,180		
September 2–30	1,360		
October 1–18	1,300		

[a] Ice affected.

Natural Environmental Radioactivity in South Florida Sands and Soils February-June 1968

Douglas H. Keefer and *Maxwell Dauer*[1]

An investigation of the naturally occurring gamma-emitting radionuclides present in selected sands and soils of south Florida was conducted. Although the primary interest was in the natural environmental radioactivity from uranium-238, radium-226, thorium-232, and potassium-40, the concentrations of five fission products were also determined to minimise the error in computing the concentrations of the four naturally occurring radionuclides. The determination of these nine radionuclides in 45 environmental samples was performed by the linear least-squares method of analysis utilising a computer.

A comprehensive radiological surveillance study of natural environmental radioactivity was the first to be conducted in south Florida with the exception of the Turkey Point Nuclear Reactor Programs of the Public Health Service and the State of Florida. The Turkey Point studies consisted of soil analyses for potassium-40, radium-226, and thorium-232, on a limited scale. There had been no attempt, however, to assay soil and sand samples beyond this area.

The sampling criterion was based upon differences in the soil associations of south Florida (*1*). The wide variety of sand and soil types with variations from the west to east coast and into the Keys provided ample environmental sampling opportunities.

The environmental radiological data on the naturally occurring radionuclides in south Florida, obtained through this study, will provide those agencies interested in establishing an environmental baseline with an indication of radionuclide concentrations. This information is necessary because the operation of nuclear power reactors in south Florida will require the establishment of preoperational baseline determinations by the responsible State and federal health agencies.

In addition to the radiological surveillance data obtained, geological formation data are also indicated by the presence of four natural sources of radioactivity (uranium-238, radium-226, thorium-232, and potassium-40). For example, the Miami oolite formation of the Homestead area extends beneath the surface and reappears in the western Keys. Other geological formations reported in the literature were confirmed by this radiological analysis.

Review of Florida environmental radioactivity

Williams et al. (*2*) and Roessler (*3*) state that the natural environmental radioactivity occurring in Florida moves in the environment because of phosphate mining, phosphate fertilizer production, and subsequent use of byproducts. Other typical sources of environmental radioactivity, such as uranium mining, concentrating or milling; nuclear fuel fabrication or reprocessing; and commerical radioactive waste disposal activities; do not take place in Florida.

Recent studies conducted by the Florida State Board of Health and the U.S. Public Health Service were the principal sources of data on radioactivity in the south Florida environment. These surveys were primarily concerned with fallout and the potential contamination of the environment with reactor byproducts in the vicinity of the Turkey Point Nuclear Reactor site (*4*). However, the naturally occurring radionuclides were also investigated because of their analytical interference with man-made radionuclides. Potassium-40, thorium-232, and radium-226 concentrations have been reported in soil samples collected by the U.S. Public Health Service's Southeastern Radiological Health Laboratory since 1966 (*5*).

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Aerial radiometric surveys of the Atlantic Coast beaches from Florida to North Carolina were conducted by the U.S. Geological Survey and the U.S. Atomic Energy Commission during May to November 1953 (*6*). These surveys did not locate any areas of significantly high gamma radiation in southern Florida.

Mahdavi (*7*) states that during weathering, thorium and uranium are separated to the extent that tetravalent uranium is oxidized to the hexavalent state, leached, and transported in solution as the soluble uranyl ion or its soluble complexes. By comparison, thorium, having only a tetravalent state, remains in primary or secondary resistate[1] minerals (*8*), which concentrate in residual soils (*9*) or are transported as clastic particles. Unoxidized tetravalent uranium in resistates, for example, zircon ($ZrSiO_4$), remains with thorium.

The assumption of secular radioactive equilibrium between thorium and uranium has not been experimentally proved because of sampling and experimental difficulties, but earlier work (*10*) and general agreement with independent and spectrochemical potassium values (*11*) support the assumption. If the thorium and uranium are largely contained in quartz and other resistates (e.g., zircon and monazite), it is unlikely that they have been separated from their radioactive daughters to an important extent. Conversely, any nonresistant or fine grained mineral in which the thorium and uranium are likely to be out of secular radioactive equilibrium with their daughter products is also likely to be quickly removed by the action of waves on the beaches. Carbonate shells formed in the last hundred thousand years are known to be out of equilibrium by not having all the radionuclide daughters that could be supported by the uranium present. To the extent that shells and shell debris are present on the beach, there will be more uranium present than that indicated by analysis of the gamma radiation from the beach (*7*).

Osmond (*12*) states that the coral formations in southern Florida, including Key Largo limestone and Miami oolite, consist of aragonitic carbonates. These have a much higher uranium content than those of normal limestones. The important determining factor is probably the "room" in the crystal lattice of argonite rather than some function of organic activity involved in its formation.

Mahdavi (*7*) further states that, in general, there seemed to be consistent changes from shore to dune across all beach profiles. These changes in concentrations of thorium and uranium and the thorium to uranium ratio must be largely due to the relative proportions of clay and radioactive resistate mineral, particularly when more than 1 to 2 p.p.m. thorium and 0.3 to 0.6 p.p.m. uranium are found. These latter concentrations are most frequently found in pure beach sands and may be considered as the average thorium and uranium content of quartz and feldspar.

Mahdavi's (*7*) study gives most of the available information on thorium, uranium, and potassium concentrations in beach sands with four conclusions:

1. Thorium above 1–2 p.p.m. and uranium above 0.3–0.6 p.p.m. in beach sands are contained in dense, resistate minerals, such as monazite, zircon, and xenotime.

2. Most beaches have a thorium to uranium ratio of 2.5–3, and only the Galveston Island, Tex., and the Cape Cod, Mass., beaches had a thorium to uranium ratio near the 3.8 crustal average.

3. The concentrations of thorium, uranium, and potassium and the thorium to uranium ratio can be related to provenance[2] and beach processes in several cases and can probably be used as natural radioactive tracers and process indicators in many geological situations.

4. The most frequent concentrations found in beach sands are 1–2 p.p.m. thorium and 0.3–0.6 p.p.m. uranium, but the mean concentrations are unknown, being greatly affected by the irregular occurrence of dense resistate minerals, such as monazite and zircon.

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[1] Resistate, any of the class of sediments, as sand or sandstone consisting chiefly of minerals resistant to weathering.

[2] Provenance, place or source of origin.

Sampling and analytical procedures

Samples of sand and soil were obtained by selecting an appropriate area of approximately 3,000 cm². The surface of this area was cleared of debris and sampled to a depth of 5 to 10 cm. The individual samples were homogeneously mixed when dry, and large components (e.g., pieces of limestone) were crushed. The sample was then placed in a tared polyethylene Marinelli beaker, tamped to a 2-liter volume and weighed. The range of sample weights was 1.9 kg to 3.6 kg, representing light organic soil to insoluble Miami oolite limestone composition, respectively.

A Nuclear Data 180 counting system was used to perform the gamma pulse-height analysis. The detector system consisted of a 3-by 3-inch aluminum clad NaI(Tl) crystal detector surrounded by a 2-inch-thick cylinder of lead with an inside diameter of 8 inches. This shield was lined with 1 mil of copper and 1/2 mil of aluminum foil to reduce the production of the characteristic lead x ray. The high-voltage power supply was stabilized with a voltage regulator, and line voltage fluctuations were observed to be minimal.

Standardization

The pulse-height analyzer was calibrated to give a channel coefficient of 10 keV per channel using a combination disc source of cesium–137 and cobalt–60. This calibration was repeated for each sample or standard counted.

The counting system was standardized for the natural radionuclides of interest: potassium–40, radium–226 (in equilibrium), uranium–238, and thorium–232. In addition, standard samples of the following fission products were prepared: cerium-praseodymium–144, ruthenium-rhodium–106, cesium-barium–137, zirconium-niobium–95, and manganese–54. All standards were prepared in a 2-liter volume of dry ACS grade sodium chloride weighing 2.855 kilograms to approximate the mean density of the sand and soil samples, which had a range of 1.9 kg to 3.6 kg per 2-liter volume. Backgrounds were subtracted from the standards and net counts used to determine sample activity.

An extended counting period of 200 minutes (four times that normally used by environmental radiological laboratories utilizing 4- by 4-inch crystal detectors) was used. This increased counting time helped overcome the poorer sensitivity of the 3- by 3-inch crystal detector, permitting a more reliable comparison of low-level environmental data.

Data computations

Normally, to correct each sample spectrum for the contribution from natural background radiation, the background spectrum is first subtracted from the sample spectrum. This study used a different approach. The method used consisted of selecting a composite natural background spectrum representative of the counting system being used. These background data were added as a standard spectrum to the computer program. A ten component linear least-squares fitting program was used to determine the magnitude of each of the nine radionuclides of interest and the ratio of the individual background spectrum to the composite background spectrum. The ratio of the background spectra, called the background variation ratio, should be close to 1.000. This has the effect of evaluating the reliability of the least-squares gamma analysis computation as a function of the sample's background deviation from unity (table 1). The inclusion of 95-percent confidence limits (C.L.) for this background variation also provides a range in which the expected variation should occur. Background variations outside the 95-percent confidence limits occurred in less than 10 percent of the results with most variations occurring in less than 5 percent. The presence of radium–226 daughter products not in equilibrium accounts for this variation of sample background.

The solution of complex gamma-ray spectra containing ten components (including natural background) further complicated by gain shifts of the sample and each of the standard components, necessitated the use of a linear least-squares fitting program developed by R. L. Health et al. (*13*) for an IBM 7040. This program included a gain shift routine.

The final product of this program is an intensity factor of the standard and its standard deviation (SD) that is present in the sample. This value, when multiplied by the total activity of the standard and divided by the weight of the sample

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Table I. Environmental analysis of southern Florida sands and soils, February–June 1968[a]

Sampling location	Sample number and type	Sample weight (kg)	Background variation ratio	Radionuclide concentration (pCi/kg, dry weight)							
				^{238}U	^{144}Ce-Pr	^{106}Ru-Rh	^{137}Cs-Ba	^{95}Zr-Nb	^{40}K	^{226}Ra	^{232}Th
Marco Island (SL)[c]	1 Sand	3.30	1.001 ± 0.020	110 ± 30	480 ± 100	ND	ND	17 ± 12	300 ± 290	1,080 ± 280	140 ± 30
Marco Island (BB)[b]	2 Sand	3.22	.970 ± .030	120 ± 30	380 ± 170	ND	41 ± 26	31 ± 13	ND	1,080 ± 310	160 ± 30
Everglades City	3 Soil	3.60	.973 ± .010	120 ± 60	640 ± 190	240 ± 230	48 ± 38	30 ± 14	510 ± 340	1,100 ± 320	200 ± 30
Chokoloskee	4 Sand	3.40	1.071 ± .005	240 ± 70	2,070 ± 490	ND	190 ± 50	44 ± 24	880 ± 530	6,220 ± 990	450 ± 60
Ochopee	5 Soil	3.00	1.046 ± .034	290 ± 70	1,080 ± 420	ND	ND	37 ± 7	1,030 ± 620	5,630 ± 1,110	390 ± 60
Midway	6 Soil	2.40	1.097 ± .042	400 ± 120	2,030 ± 600	ND	850 ± 130	ND	1,610 ± 950	9,150 ± 1,620	730 ± 70
Sweetwater	7 Soil	3.20	1.034 ± .034	210 ± 70	1,730 ± 390	ND	330 ± 70	120 ± 30	840 ± 550	6,300 ± 1,080	400 ± 50
Hialeah	8 Soil	2.60	1.096 ± .024	280 ± 60	1,360 ± 390	ND	1,350 ± 80	26 ± 22	880 ± 530	4,190 ± 970	330 ± 50
South Miami	9 Soil	2.70	1.100 ± .028	160 ± 60	970 ± 370	ND	330 ± 70	ND	800 ± 560	5,570 ± 940	340 ± 40
Pembroke Park	10 Soil	3.23	.995 ± .020	140 ± 30	840 ± 180	ND	470 ± 30	75 ± 13	380 ± 380	980 ± 310	110 ± 30
	11 Soil	3.35	.983 ± .012	110 ± 20	380 ± 100	ND	18 ± 15	15 ± 8	330 ± 300	510 ± 180	88 ± 10
Golden Beach (SL)	12 Sand	3.40	.997 ± .029	96 ± 46	440 ± 240	ND	ND	ND	ND	1,140 ± 430	150 ± 30
Golden Beach (BB)	13 Sand	3.30	0.988 ± .021	59 ± 23	720 ± 180	350 ± 240	71 ± 26	34 ± 13	350 ± 310	1,210 ± 310	130 ± 30
Miami Beach (SL)	14 Sand	2.95	1.003 ± .013	100 ± 20	460 ± 120	220 ± 180	ND	ND	430 ± 240	790 ± 220	82 ± 14
Miami Beach (BB)	15 Sand	3.15	1.016 ± .016	90 ± 28	370 ± 130	ND	47 ± 21	18 ± 11	260 ± 260	740 ± 240	80 ± 16
Key Biscayne (SL)	16 Sand	2.80	1.028 ± .030	110 ± 30	530 ± 180	ND	ND	21 ± 14	650 ± 340	940 ± 310	85 ± 20
Key Biscayne (BB)	17 Sand	3.45	.970 ± .017	90 ± 27	680 ± 140	300 ± 200	65 ± 22	44 ± 11	300 ± 290	800 ± 250	110 ± 20
Upper Key Largo	18 Soil (Oolite)	2.98	1.044 ± .032	330 ± 80	1,850 ± 450	ND	110 ± 50	110 ± 30	990 ± 320	4,810 ± 950	310 ± 30
Homestead Bayfront Park	19 Soil	2.41	1.062 ± .014	280 ± 70	1,250 ± 370	ND	310 ± 50	40 ± 24	770 ± 570	5,440 ± 970	410 ± 50
Homestead	20 Soil	2.10	1.016 ± .035	230 ± 90	560 ± 500	ND	850 ± 120	94 ± 30	930 ± 830	3,720 ± 1,380	200 ± 60
	21 Soil (Oolite)	2.81	1.072 ± .031	230 ± 60	1,190 ± 370	ND	130 ± 70	31 ± 24	920 ± 560	5,640 ± 990	330 ± 50
	22 Soil	2.16	1.045 ± .038	300 ± 80	1,230 ± 440	ND	1,030 ± 80	34 ± 29	740 ± 660	5,290 ± 1,210	390 ± 60
	23 Soil	2.10	1.071 ± .025	370 ± 80	1,330 ± 430	ND	950 ± 80	66 ± 28	830 ± 600	5,600 ± 1,190	390 ± 60
	24 Soil	2.80	1.066 ± .028	220 ± 30	1,090 ± 370	530 ± 480	500 ± 70	69 ± 24	ND	5,000 ± 1,030	332 ± 50
	25 Soil	2.40	1.128 ± .051	350 ± 80	910 ± 470	ND	1,090 ± 90	71 ± 29	930 ± 330	7,550 ± 1,330	430 ± 70
	26 Soil	1.93	1.048 ± .030	400 ± 80	ND	ND	560 ± 50	59 ± 23	750 ± 540	4,120 ± 980	240 ± 30
Turkey Point	27 Sand	3.60	1.332 ± .089	220 ± 60	1,390 ± 360	ND	ND	76 ± 24	750 ± 540	4,530 ± 910	320 ± 30
Homestead	28 Soil (Silt)	2.10	1.103 ± .029	360 ± 80	900 ± 450	ND	120 ± 70	33 ± 30	1,020 ± 700	7,330 ± 1,290	450 ± 60
Turkey Point	29 Soil (Silt)	.80	.962 ± .080	390 ± 210	ND	520 ± 260	ND	130 ± 80	3,480 ± 1,970	5,390 ± 1,970	750 ± 130
Cross Key	30 Soil	3.20	1.096 ± .034	120 ± 60	1,790 ± 430	ND	130 ± 50	100 ± 20	760 ± 520	4,700 ± 930	270 ± 50
Flamingo (SL)	31 Sand	2.30	1.075 ± .023	84 ± 47	ND	ND	52 ± 38	28 ± 20	820 ± 460	1,050 ± 440	140 ± 30
	32 Sand	1.90	1.092 ± .033	150 ± 60	ND	ND	160 ± 50	38 ± 26	ND	1,610 ± 600	320 ± 40
	33 Sand (Clay)	2.70	1.078 ± .041	250 ± 90	960 ± 530	ND	130 ± 70	ND	2,430 ± 760	7,750 ± 1,580	600 ± 80
	34 Sand	2.10	1.082 ± .090	120 ± 70	ND	ND	72 ± 57	36 ± 29	910 ± 710	1,570 ± 670	240 ± 40
Hens and Chickens Reef	35 Sand	2.40	.995 ± .014	150 ± 30	500 ± 160	310 ± 240	ND	35 ± 13	580 ± 320	810 ± 290	62 ± 19
Chev Shore Reef	36 Sand	2.40	1.025 ± .014	120 ± 30	340 ± 160	270 ± 240	ND	26 ± 13	530 ± 320	1,060 ± 290	65 ± 18
Atlantic Ocean bottom	37 Sand	3.00	.980 ± .019	200 ± 40	880 ± 240	ND	40 ± 27	ND	ND	1,070 ± 330	130 ± 30
Islamorada (BB)	38 Sand	2.50	1.030 ± .018	150 ± 40	730 ± 210	330 ± 300	150 ± 30	94 ± 17	ND	1,300 ± 380	94 ± 24
Long Key (SL)	39 Sand	1.90	.997 ± .017	210 ± 50	ND	ND	ND	38 ± 19	ND	960 ± 430	90 ± 26
Long Key (BB)	40 Sand	2.50	.990 ± .015	94 ± 31	380 ± 180	410 ± 260	47 ± 27	67 ± 15	400 ± 340	1,070 ± 320	81 ± 21
Marathon (SL)	41 Sand	2.60	.988 ± .016	130 ± 30	480 ± 170	330 ± 260	ND	30 ± 14	ND	1,080 ± 310	82 ± 20
Marathon (BB)	42 Sand	2.50	.971 ± .017	120 ± 40	470 ± 190	ND	ND	30 ± 15	580 ± 370	1,290 ± 340	89 ± 22
Bahia Honda Park	43 Sand	3.10	.997 ± .020	110 ± 40	620 ± 190	ND	34 ± 28	31 ± 15	ND	1,380 ± 340	120 ± 20
Key West (SL)	44 Sand	2.73	1.025 ± .023	210 ± 60	780 ± 200	ND	ND	31 ± 20	610 ± 400	4,970 ± 820	260 ± 40
Key West (BB)	45 Sand	3.00	1.038 ± .025	200 ± 50	1,010 ± 300	ND	57 ± 41	43 ± 20	620 ± 460	5,120 ± 770	270 ± 40

[a] The error expressed is the relative 1.96-sigma counting error.

[b] BB, beach back.

[c] SL, sea level, front beach.

ND, nondetectable.

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in kilograms, expresses the activity of the respective radionuclide per kilogram of sample. The 95-percent confidence limit is obtained by following the above steps with the SD and then multiplying the result by 1.96.

Analysis of beach sands

The profile of a beach in a line perpendicular to the water's edge consists of a front beach at sea level, the berm, the back beach, and finally the dune. In this study, beach-sand samples were collected from the front and back beach areas (whenever the beach was wide enough) to present a profile. This sampling procedure was followed to permit observation of the systematic changes in the thorium to uranium ratio from shore to dune reported by Mahdavi (7). The two sampling areas (the front and back beaches) were reported to be the low and high ratios, respectively. The same phenomenon was observed in the beach sands of south Florida.

The thorium-232 and uranium-238 values reported for south Florida were within the range of the most frequent concentrations reported for the north Gulf and Atlantic Coast beaches (7). However, as observed in table 2, the thorium

Table 2. Natural environmental radioactivity in the sands and soils of southern Florida, February–June 1968

Sample number[a]	Concentration (dry weight)				Th/U ratio
	Potassium (mg/g)	Radium-226 (pg/g)	Uranium-238 (p.p.m.)	Thorium-232 (p.p.m.)	
Sand:					
1	0.42±0.34[b]	1.0 ±0.2[b]	0.3±0.1[b]	1.2±0.2[b]	3.7
2	ND	1.0 ± .3	.4± .1	1.4± .2	4.0
4	.07± .02	6.1 ±1.0	.7± .2	4.2± .5	5.8
12	ND	1.1 ± .4	.3± .1	1.4± .3	4.8
13	.42± .36	1.2 ± .3	.2± .1	1.4± .2	7.7
14	.51± .28	.7 ± .2	.3± .1	.7± .1	2.4
15	ND	.7 ± .2	.3± .1	.7± .1	2.7
16	.76± .40	.9 ± .3	.3± .1	.8± .2	2.2
17	.46± .30	.9 ± .2	.3± .1	1.0± .2	3.7
27	.90± .63	4.5 ± .9	.7± .2	2.9± .5	4.4
31	.96± .56	1.0 ± .4	.3± .1	1.3± .3	5.0
32	ND	1.6 ± .6	.5± .2	2.9± .4	6.2
33	2.86± .91	7.6 ±1.5	.7± .3	6.2± .7	8.3
34	1.08± .84	1.5 ± .6	.4± .2	2.1± .4	5.9
35	.68± .38	.8 ± .3	.5± .1	.6± .2	1.2
36	.02± .38	1.0 ± .2	.4± .1	.6± .2	1.6
37	ND	1.1 ± .3	.6± .1	1.2± .2	2.0
38	ND	1.3 ± .4	.4± .1	.8± .2	1.9
39	ND	.8 ± .4	.7± .2	.8± .3	1.1
40	.48± .40	1.1 ± .3	.3± .1	.7± .2	2.6
41	ND	1.0 ± .3	.5± .1	.7± .2	1.6
42	.66± .43	1.2 ± .3	.4± .1	.8± .2	2.3
43	ND	1.5 ± .3	.3± .1	1.1± .2	3.4
44	.72± .54	4.9 ± .8	.6± .1	2.3± .3	3.6
45	.73± .54	5.0 ± .8	.6± .2	2.4± .3	4.0
Soil:					
3	.60± .40	1.1 ± .3	.4± .1	1.8± .2	5.0
5	1.21± .72	5.5 ±1.1	.9± .2	5.3± .5	6.2
6	1.90±1.12	9.0 ±1.8	1.2± .4	6.5± .8	5.5
7	.99± .65	6.2 ±1.0	.6± .2	3.6± .5	5.6
8	1.05± .63	4.1 ± .9	.8± .2	3.0± .4	3.8
9	.94± .70	5.5 ± .9	.5± .2	3.1± .4	6.4
10	.20± .35	.9 ± .3	.4± .1	1.0± .2	2.3
11	.30± .23	.5 ± .2	.3± .1	.8± .1	2.2
18	1.16± .61	4.7 ± .9	1.0± .2	2.8± .5	2.9
19	.90± .67	5.3 ± .9	.8± .2	3.7± .5	4.5
20	1.10± .97	3.6 ±1.3	.7± .3	1.8± .5	2.6
21	1.08± .66	5.5 ± .9	.7± .2	3.0± .4	4.3
22	.87± .78	5.1 ±1.2	.9± .2	3.5± .5	4.0
23	.98± .78	5.8 ±1.2	1.1± .2	3.2± .5	2.9
24	ND	5.5 ±1.0	.7± .1	3.0± .5	4.6
25	1.09± .30	7.4 ±1.2	1.1± .2	3.8± .6	4.0
26	.88± .64	4.0 ± .9	1.2± .2	2.1± .3	1.8
28	1.20± .82	7.1 ±1.3	1.1± .2	3.9± .6	3.6
29	4.10±2.31	5.4 ±1.9	1.2± .6	6.7±1.2	5.8
30	.80± .61	4.6 ± .9	.4± .2	2.4± .4	6.0

[a] Sampling locations are given in table 1.

[b] The error expressed is the relative 1.96-sigma-counting error.

ND, nondetectable.

to uranium ratios are above the mean range of 2.5–3.0 reported by Mahdavi, with the exception of the Key Largo to Marathon sampling locations (numbers 35 to 42). The mean thorium to uranium ratio for all beach sands collected in south Florida was 3.7, within a range of 1.1 to 8.3. The mean concentration for thorium-232 was 1.6 ± 0.3 p.p.m., in a range of 0.6 to 6.2 p.p.m. The mean concentration for uranium-238 was 0.7 ± 0.1 p.p.m., with a range of 0.2 to 0.7 p.p.m.

The beach sands of south Florida have a mean thorium to uranium ratio of 3.7. This ratio is considerably higher than those reported for the north Florida Gulf Coast and south Atlantic Coast beaches, which are 2.1 and 2.8, respectively. The south Florida thorium to uranium ratio approximates the earth's crustal average of 3.8, as do the beaches of Galveston, Tex., and Cape Cod, Mass. It appears that the geological formation of Miami oolite limestone, so prevalent in south Florida, is responsible for the higher ratio.

Seven pairs of the beach sand samples confirmed that the back beach thorium to uranium ratio is higher than the front beach ratio in south Florida sands. This was also observed by Mahdavi for the Gulf Coast and Atlantic Coast beaches. This change in concentration is due to the relative proportions of clay and radioactive resistate minerals, which vary from the front of the beach to the back of the beach, as influenced by the action of sea.

Table 2 shows that the highest thorium to uranium ratios generally appear in samples also containing the highest radium-226 concentrations. The possibility of radium-226 interfering with uranium and thorium results is minimized, however, by examining the analysis of samples having similarly high thorium to uranium ratios with low radium-226 activity. The mean radium-226 content of the south Florida sands was 2.0 ± 0.5 pg/g, with a range of 0.7 to 7.6. The sand samples, consisting primarily of Miami oolite limestone had the highest average concentration of radium-226, approximately 5 pg/g. Those sand samples consisting of Key Largo limestone had the lowest average radium-226 concentration, approximately 2 pg/g.

The fission products detected in the south Florida sands had maximum values (per kilogram of dry sample weight) as follows: cerium-praseodymium-144, 2,070 pCi; ruthenium-rhodium-106, 410 pCi; cesium-barium-137, 180 pCi; and zirconium-niobium-95, 110 pCi.

Relatively low concentrations of natural potassium are found in south Florida sands and soils. The results were reported as nondetectable within this confidence interval in several cases. This phenomenon has also been observed by the Public Health Service and Florida State Board of Health in their environmental surveys of south Florida soil (*5*, *14*). The mean concentration of natural potassium (determined by potassium-40 assay) was 0.53 ± 0.32 mg/g of sand, with a range from nondetectable to 2.9 mg/g. The mean potassium concentration in soils was 1.1 ± 0.7 mg/g, with a range of 0.39 to 4.1 mg/g. The potassium content of 0.046 percent reported by Mahdavi for the north Florida Gulf Coast beach is comparable to the south Florida beach value of 0.053 percent.

Analysis of soil

The 20 soil samples assayed provide an insight into the naturally occurring environmental radioactivity that exists throughout south Florida. The mean thorium to uranium ratio in soil samples was 4.2, in a range of 1.8 to 6.6 (table 2). The mean thorium-232 concentration was 3.3 ± 0.5 p.p.m., in a range of 0.8 to 6.7 p.p.m. The mean uranium-238 concentration was 0.8 ± 0.2 p.p.m. in a range of 0.3 to 1.2 p.p.m.

The environmental analysis of natural radioactivity in south Florida soils indicates a mean thorium to uranium ratio of 4.2. This ratio is the result of a two-fold increase in the mean thorium-232 concentration, accompanied by only a small increase in the mean uranium-238 content over the reported concentrations for sands in south Florida. The radium-226 concentration in soil samples was approximately 2.5 times the radium-226 found in sand samples. Since radium-226 is a daughter product of the uranium-238 series, the difference between soil and sand concentrations must be the result of nonsecular equilibrium between daughter products washed away by the action of waves on the beach. The parent radionuclide, uranium-238, is present in equal quantities (approximately 0.75 p.p.m.) in both sand and soil.

The geological formation of southern Florida consists of two major limestone structures. Mi-

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ami oolite, comprising the east coast ridge on the mainland, appears in the Homestead area (sample number 21), descends to form the floor of the southern Everglades and is again observed at Flamingo (sample numbers 31 through 34). The oolite formation then emerges west of Big Pine Key and influences the natural environmental radioactivity of Key West (sample numbers 44 and 45). The Key Largo limestone formation (having low thorium-232 and radium-226 concentrations) forms the Keys and the offshore ocean floor from Key Largo to Marathon (sample numbers 35 through 42) and is observed radiometrically at eight sampling locations in this study.

The radioanalysis of samples for natural environmental radioactivity collected from the Turkey Point Nuclear Reactor area (sample numbers 19 through 29) will assist the Public Health Service and the Florida State Board of Health in preoperational surveys. The range of uranium-238 in these samples was from 0.66 to 1.2 p.p.m.; the range of thorium-232 was from 1.8 to 3.8 p.p.m., with thorium to uranium ratios from 1.8 to 5.5.

Many soil samples contained pieces of Miami oolite, since the widely distributed Perrine-Ochopee soil association consists of marly materials overlying limestone. This oolite contribution is significant in determining the radiological environmental profile of the area. The PHS analysis of soil samples from this area ascertained similar levels of natural environmental activity.

The fission products detected in south Florida soils had value ranges, (per kilogram of dry sample weight) as follows: cerium-praseodymium-144, nondetectable to 2,030 pCi; ruthenium -rhodium-106, nondetectable to 830 pCi. Ruthenium-rhodium-106 values were less than the detectable levels (below the 95-percent confidence limits) for most soil samples assayed. Values of cesium-barium-137 ranged from nondetectable to 1,350 pCi; and zirconium-niobium-95, from nondetectable to 120 pCi. Manganese-54 was detectable (above the 95-percent confidence limit) in only two of the 45 samples. This expected frequency supports the observation that manganese-54 no longer contributes significantly to environmental radioactivity in south Florida.

Conclusion

Four conclusions can be drawn from this environmental investigation of natural radioactivity in south Florida:

1. The thorium to uranium ratio of Florida's southern peninsula is significantly higher than the reported ratio of the north Florida Gulf coast and south Atlantic coast beaches. This higher ratio is caused primarily by the presence of Miami oolite limestone formation indigenous to this area. High radium-226 concentrations, approximately 5 pg/g, can also be expected when a sample contains a high percentage of Miami oolite.

2. If a sample contains Key Largo limestone, it is anticipated that the thorium to uranium ratio will be approximately 2.0, because thorium-232 concentrations are about one-third of the range found in Miami oolite. Radium-226 activity in a sample containing a significant amount of the Key Largo limestone will be approximately 2 pg/g.

3. The uranium-238 concentration in sands and soils of southern Florida is approximately 0.75 p.p.m. This level of natural environmental radioactivity is expected because of the higher uranium content of specific limestone formations native to south Florida.

4. The potassium concentrations of south Florida beach sands and sandy-type soils compare closely with the reported values from the north Florida Gulf coast area.

REFERENCES

(1) SMITH, F. B., R. G. LEIGHTY, R. E. CALDWELL, and V. W. CARLISLE. Principal Soil Areas of Florida, Bulletin 717. Florida Agriculture Experiment Stations (1967).

(2) WILLIAMS, E. G., J. C. GOLDEN, JR., C. E. ROESSLER, and U. CLARK. Study of Natural Background Radiation in Florida. Florida State Board of Health, Jacksonville, Fla. (1965).

(3) ROESSLER, C. E. Ph. D. dissertation, University of Florida. Gainesville, Fla. (1967).

(4) FLORIDA STATE BOARD OF HEALTH, DIVISION OF RADIOLOGICAL HEALTH. Radiological surveillance program of the Turkey Point nuclear power reactor area, Report #1 (October 1966).

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(*5*) PHS, SOUTHEASTERN RADIOLOGICAL HEALTH LABORATORY. Turkey Point Nuclear Reactor Project data report, 1966–1968. SERHL, Montgomery, Ala. (1968).

(*6*) MOXAM, R. M. Search for and Geology of Radioactive Deposits, TEI-330. Trace Elements Investigative Report, U.S. Geological Survey (1953) pp. 280–292.

(*7*) MAHDAVI, A. The Natural Radiation Environment. University of Chicago Press (1964) pp. 87–114.

(*8*) PLILER, R. and J. A. S. ADAMS. Distribution of thorium, uranium and potassium in the Moncos shale. Geochim Cosmochim Acta 26:1115–1135 (1962).

(*9*) ADAMS, J. A. S. and K. A. RICHARDSON. Thorium, uranium, and zirconium concentrations in Bauxite. Econ Geol 55:1060–1063 (1960).

(*10*) MURRAY, E. G. and J. A. S. ADAMS. Thorium, uranium and potassium in some sandstones. Geochim Cosmochim Acta 13:260–269 (1958).

(*11*) HSU, K. J. Texture and mineralogy of the recent sands of the Gulf Coast. J Sed Petrology 30:380–403 (1960).)

(*12*) OSMOND, J. K. The Natural Radiation Environment. University of Chicago Press (1964) pp. 153–159.

(*13*) HEATH, R. L., R. G. HELMER, D. D. METCALF, and G. A. CAZIER. A linear least-squares fitting program for the analysis of gamma-ray spectra including a gain-shift routine, IDO-17015 (1964).

(*14*) FLORIDA STATE BOARD OF HEALTH, DIVISION OF RADIOLOGICAL HEALTH. Report of Florida radiological data—environmental monitoring programs—1967. (1968).

SECTION I. MILK AND FOOD

Milk Surveillance, May 1970

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation and/or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Bureau of Radiological Health and the Bureau of Foods, Pesticides and Product Safety, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

> Pan American Milk Sampling Program (Pan American Health Organization and U.S. Public Health Service)—5 sampling stations
>
> Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that occur in, or are formed as a result of, nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements, calcium and potassium, which are found in milk, have been used as a means for assessing the biological behavior of

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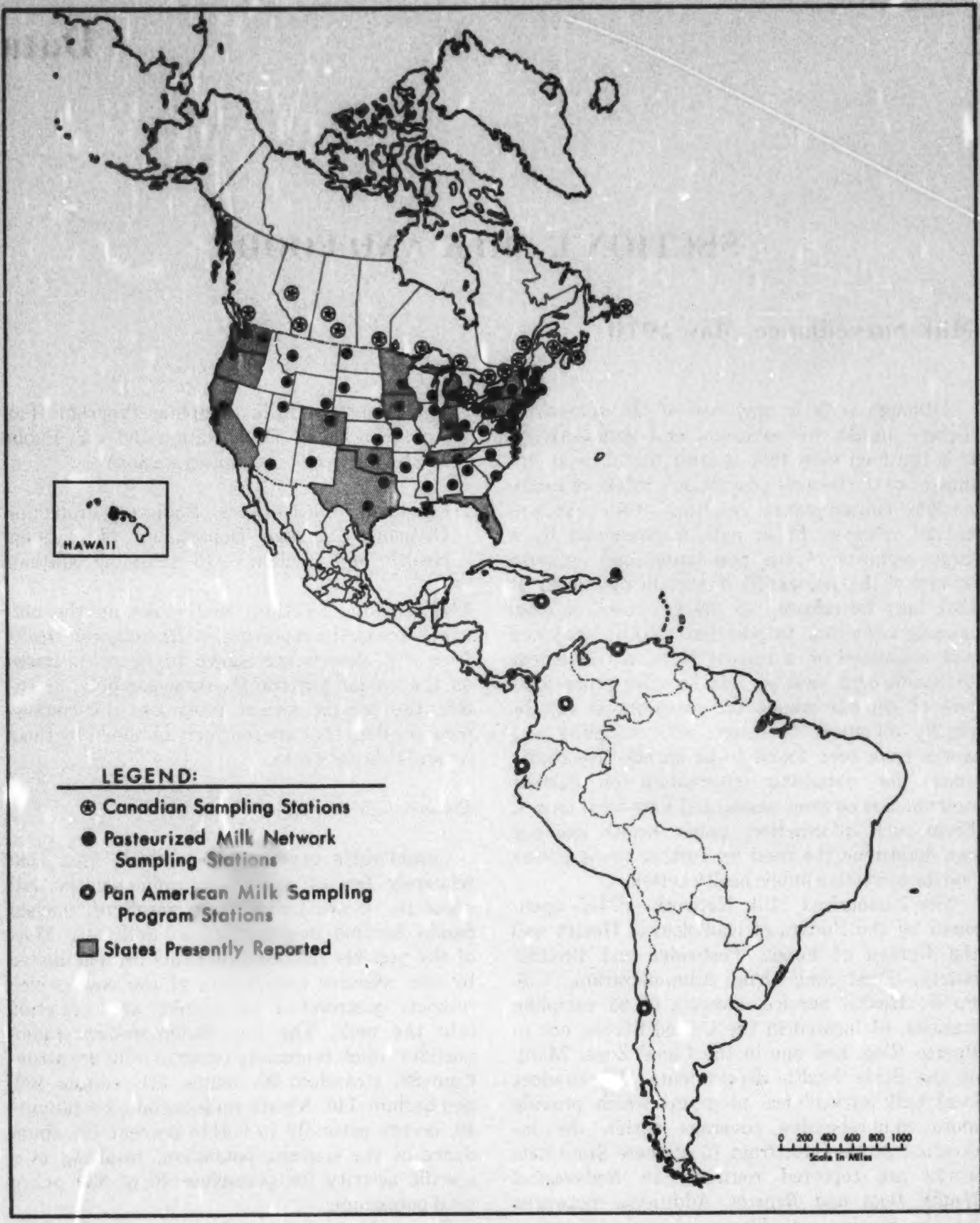
HAWAII
LEGEND:
⊛ Canadian Sampling Stations
● Pasteurized Milk Network Sampling Stations
○ Pan American Milk Sampling Program Stations
▨ States Presently Reported
0 200 400 600 800 1000
Scale in Miles

Figure 1. Milk sampling networks in the Western Hemisphere

metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variation, expressed in terms of 2-standard deviations for these concentrations are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for the period, May 1963–March 1966 (*3*) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Bureau of Radiological Health conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested public health radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted during July–September 1969, with 31 laboratories participating in an experiment on milk samples containing known concentrations of strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. Of the 18 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 14 participated in the experiment.

The iodine-131 and cesium-137 results show much improvement over previous tests. Barium-140 results also look good, which is encouraging, since this is the first time barium-140 was analyzed for this type of experiment. However, strontium-89 and strontium-90 analyses still need improvement (*5*). Keeping these possible differences in mind, integration of the data from the various networks can be undertaken without introducing a serious error due to disagreement among the independently obtained data.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methodologies, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports.*

A recent article (*6*) summarizes the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and earlier data articles for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. The frequency of collection and analysis varies not only among the networks but also at different stations within some the of networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short time periods, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data presentation also reflects whether raw or pasteurized milk was collected. A recent analysis (*7*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or

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sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant. Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard deviation counting errors or 2-standard deviation total analytical errors from replicate analyses experiments (*3*). The practical reporting level reflects additional analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks give practical reporting levels greater than those above. In these cases the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurement equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical errors or precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (3). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter
Iodine-131 Cesium-137 Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥100 pCi/liter

For iodine-131, cesium-137, and barium-140 there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions is presented below. The function of the Council is to provide guidance to Federal agencies in the formulation of radiation standards.

Radiation Protection Guides (*8, 9*)

The Radiation Protection Guide (RPG) has been defined by the Federal Radiation Council (FRC) as the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable. An RPG provides radiation protection guidance for the control and regulation of normal peacetime uses of nuclear technology in which control is exercised primarily at the source through the design and use of nuclear material. It represents a balance between the possible risk to the general public that might result due to exposures from routine uses of ionizing radiation and the benefits from the activities causing the exposure.

Table 1 presents a summary of guidelines and related information on environmental radiation levels as set forth by the FRC for the conditions under which RPG's are applicable. A more detailed discussion of these values was presented earlier (*3*).

In the absence of specific dietary data one can use milk as the indicator food item for routine surveillance. Assuming a 1-liter per day intake of milk, one can utilize the graded approach of daily intake on the basis of radionuclide content

Table 1. Radiation Protection Guides—FRC recommendations and related information pertaining to environmental levels during normal peacetime operation

Nuclide	Critical organ	RPG for individual in the general population (rad/a)	Guidance for suitable samples of exposed population group[a]				
			RPG (rad/a)	Corresponding continuous daily intake (pCi/day)	Range I[b] (pCi/day)	Range II[b] (pCi/day)	Range III[b] (pCi/day)
Strontium-89	Bone	[c] 1.5	0.5	[d] 2,000	0-200	200-2,000	2,000-20,000
	Bone marrow	[c] .5	.17				
Strontium-90	Bone	[c] 1.5	.5	[d] 200	0-20	20-200	200-2,000
	Bone marrow	[c] .5	.17				
Iodine-131	Thyroid	1.5	.5	100	0-10	10-100	100-1,000
Cesium-137[e]	Whole body	.5	.17	3,600	0-360	360-3,600	3,600-36,000

[a] Suitable samples which represent the limiting conditions for this guidance are: strontium-89, strontium-90—general population; iodine-131—children 1 year of age; cesium-137—infants.

[b] Based on an average intake of 1 liter of milk per day.

[c] A dose of 1.5 rad/a to the bone is estimated to result in a dose of 0.5 rad/a to the bone marrow.

[d] For strontium-89 and strontium-90, the Council's study indicated that there is currently no operational requirement for an intake value as high as one corresponding to the RPG. Therefore, these intake values correspond to doses to the critical organ not greater than one-third the respective RPG.

[e] The guides expressed here were not given in the FRC reports, but were calculated using appropriate FRC recommendations.

in milk samples collected to represent general population consumption. Under these assumptions, the radionuclide concentrations in pCi/liter of milk can replace the daily radionuclide intake in pCi/day in the three graded ranges.

Protective Action Guides (*10, 11*)

The Protective Action Guide (PAG) has been defined by the Council as the projected absorbed dose to individuals in the general population that warrants protective action following a contaminating event. A PAG provides general guidance for the protection of the population against exposure by ingestion of contaminated foods resulting from the accidental release or the unforeseen dispersal of radioactive materials in the environment. A PAG is also based on the assumption that such an occurrence is an unlikely event, and circumstances that might involve the probability of repetitive occurrences during a 1 or 2-year period in a particular area would require special consideration. Protective actions are appropriate when the health benefits associated with the reduction in exposure to be achieved are sufficient to offset the undesirable features of the protective actions.

Table 2 presents a summary of guidelines as set forth by the FRC for the conditions under which PAG's are applicable. A more detailed discussion of these values was presented earlier (*3*). Also given in table 2 are milk concentration for each of the radionuclides considered, in the absence of others, which if attained after an

Table 2. Protective Action Guides—FRC recommendations and related information pertaining to environmental levels during an acute contaminating event

Radionuclide	Critical organ	PAG for individuals in general population (rads)	Category (pasture-cow-milk)	
			Guidance for suitable sample, children 1 year of age	
			PAG (rads)	Maximum concentration in milk for single nuclide that would result in PAG (pCi/liter)
Strontium-89	Bone marrow	10 in first yr; total dose not to exceed 15[a, b]	3 in first yr; total dose not to exceed 5[a, b]	[c] 1,110,000
Strontium-90	Bone marrow			[c] 51,000
Cesium-137	Whole body			[c] 720,000
Iodine-131	Thyroid	30	10	[d] 70,000

[a] The sum of the projected doses of these three radionuclides to the bone marrow should be compared to the numerical value of the respective guide.

[b] Total dose from strontium-89 and cesium-137 is the same as dose in first year; total dose from strontium-90 is 5 times strontium-90 dose in first year for children approximately 1 year of age.

[c] These values represent concentrations that would result in doses to the bone marrow or whole body equal to the PAG, if only the single radionuclide were present.

[d] This concentration would result in the PAG dose based on intake before and after the date of maximum concentration observed in milk from an acute contaminating event. A maximum of 84,000 pCi/liter would result in a PAG dose if that portion of intake prior to the maximum concentration in milk is not considered. Children, 1 year of age, are assumed to be the critical segment of the population.

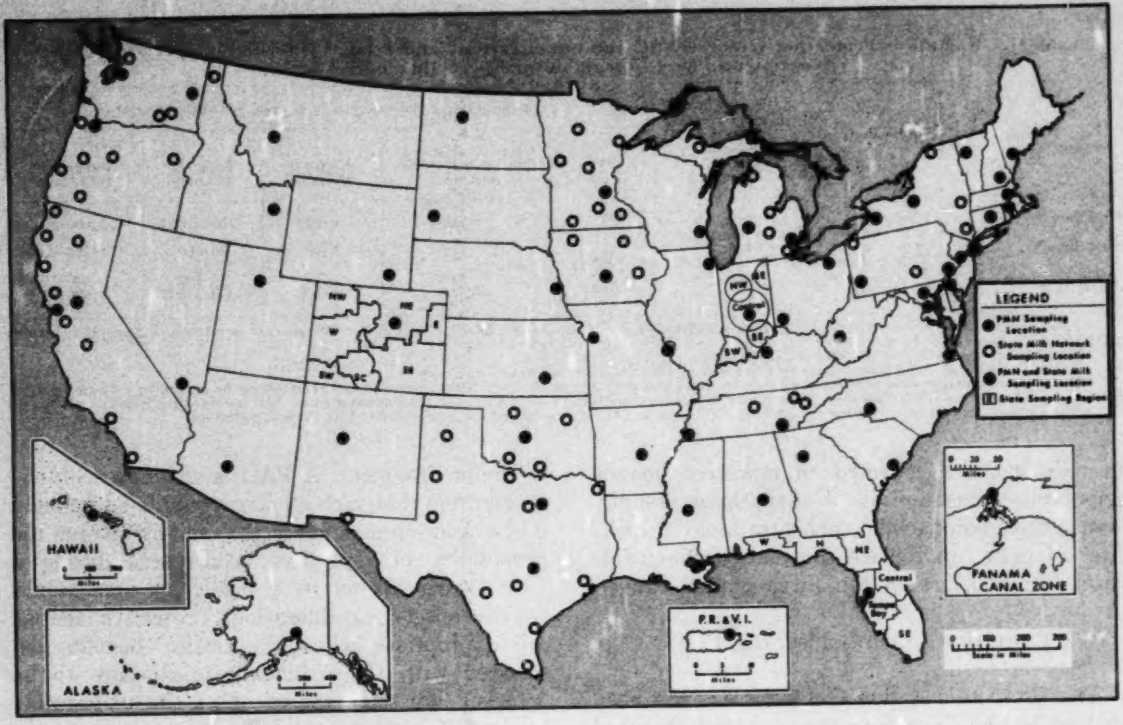

Figure 2. State and PMN milk sampling locations in the United States

acute incident, would result in doses equivalent to the appropriate PAG. These concentrations are based on a projection of the maximum concentration from an idealized model for any acute deposition and the pasture-cow-milk-man pathway, as well as an estimate of the intake prior to reaching the maximum concentration. Therefore, these maximum concentrations are intended for use in estimating future intake on the basis of a few early samples rather than in retrospective manner.

Data reporting format

Table 3 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports.* (The relationship between the PMN stations and State stations is shown in figure 2). The first column under each of the radionuclides reported gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12-monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 3, surveillance results are given for strontium-90, iodine-131, and cesium-137 for May 1970 and the 12-month period, June 1969

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Table 3. Concentration of radionuclides in milk for May 1970 and 12-month period June 1969 through May 1970

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES:								
Ala:	Montgomery[c]	P	4	6	0 (4)	0	12 (4)	10
Alaska:	Palmer[c]	P	4	5	0 (3)	0	8 (3)	4
Ariz:	Phoenix[c]	P	3	1	0 (4)	0	0 (4)	0
Ark:	Little Rock[c]	P	17	14	0 (4)	0	13 (4)	17
Calif:	Sacramento[c]	P	0	1	0 (5)	0	0 (5)	0
	San Francisco[c]	P	2	1	0 (4)	0	0 (4)	0
	Del Norte	P	25	20	0	0	17	19
	Fresno	P	2	2	0	0	0	7
	Humboldt	P	6	4	0	0	0	6
	Los Angeles	P	2	2	0	0	0	4
	Mendocino	P	5	3	0	0	0	3
	Sacramento	P	2	2	0	0	0	3
	San Diego	P	2	2	0	0	0	2
	Santa Clara	P	2	2	0	0	0	3
	Shasta	P	6	3	0	0	0	4
	Sonoma	P	4	3	0	0	0	4
Colo:	Denver[c]	P	5	5	0 (4)	0	0 (4)	2
	West	R	(d)		(e)	1	(e)	5
	Northeast	R	(d)		(e) (7)	(e)	(e) (7)	(e)
	East	R	(d)		NS	(e)	NS	(e)
	Southeast	R	(d)		NS	(e)	NS	(e)
	South central	R	(d)		NS	NS	NS	NS
	Southwest	R	(d)		NS	(e)	NS	4
	Northwest	R	(d)		(e)	(e)	(e)	(e)
Conn:	Hartford[c]	P	8	8	0 (5)	0	14 (5)	10
	Central	P	7	7	0 (5)	0	10 (5)	11
Del:	Wilmington[c]	P	8	8	0 (4)	0	5 (4)	5
D.C:	Washington[c]	P	9	7	0 (5)	0	9 (5)	6
Fla:	Tampa[c]	P	6	6	0 (2)	0	53 (2)	53
	West	R	NA	11	NA	0	NA	21
	North	R	NA	12	NA	0	NA	25
	Northeast	R	NA	7	NA	0	NA	50
	Central	R	NA	7	NA	0	NA	44
	Tampa Bay area	R	NA	7	NA	0	NA	53
	Southeast	R	NA	8	NA	0	NA	79
Ga:	Atlanta[c]	P	14	10	0 (4)	0	19 (4)	18
Hawaii:	Honolulu[c]	P	0	2	0 (4)	0	0 (4)	0
Idaho:	Idaho Falls[c]	P	4	5	0 (4)	0	6 (4)	3
Ill:	Chicago[c]	P	11	7	0 (4)	0	10 (4)	8
Ind:	Indianapolis[c]	P	8	8	0 (4)	0	0 (4)	4
	Northeast	P	9	9	0	1	15	13
	Southeast	P	14	10	0	0	15	12
	Central	P	10	9	0	0	10	10
	Southwest	P	16	11	0	0	10	12
	Northwest	P	9	10	0	0	16	17
Iowa:	Des Moines[c]	P	5	6	0 (4)	0	0 (4)	2
	Iowa City	P	NS		NS		NS	
	Des Moines	P	NS		NS		NS	
	Spencer	P	NS		NS		NS	
	Fredericksburg	P	NS		NS		NS	
Kans:	Wichita[c]	P	9	8	0 (4)	0	5 (4)	0
Ky:	Louisville[c]	P	11	8	0 (4)	0	10 (4)	4
La:	New Orleans[c]	P	15	15	0 (5)	0	23 (5)	18
Maine:	Portland[c]	P	11	11	0 (4)	0	22 (4)	22
Md:	Baltimore[c]	P	9	8	0 (4)	0	3 (4)	6
Mass:	Boston[c]	P	13	11	0 (4)	0	22 (4)	20
Mich:	Detroit[c]	P	9	8	0 (4)	0	10 (4)	8
	Grand Rapids[c]	P	19	9	0 (4)	0	9 (4)	10
	Bay City	P	NA	7	(e) (2)	(e)	10 (2)	9
	Charlevoix	P	18	12	(e) (4)	(e)	13 (4)	18
	Detroit	P	14	7	(e) (4)	(e)	6 (4)	6
	Grand Rapids	P	10	9	(e) (4)	(e)	7 (4)	11
	Lansing	P	NA	8	(e) (2)	(e)	12 (2)	15
	Marquette	P	21	13	(e) (2)	1	24 (2)	24
	Monroe	P	7	6	(e) (2)	(e)	0 (2)	2
	South Haven	P	NA	NA	(e) (4)	(e)	0 (4)	3
Minn:	Minneapolis[c]	P	9	10	0 (4)	0	9 (4)	7
	Bemidji	P	5	16	0	0	20	25
	Mankato	P	4	7	0	0	0	0
	Rochester	P	5	8	0	0	12	0
	Duluth	P	14	17	0	0	21	24
	Worthington	P	0	6	0	0	0	0
	Minneapolis	P	6	11	0	0	12	12
	Fergus Falls	P	4	8	0	0	0	11
	Little Falls	P	15	9	0	0	20	12
Miss:	Jackson[c]	P	15	12	0 (3)	0	13 (3)	12
Mo:	Kansas City[c]	P	8	8	0 (4)	0	8 (4)	2
	St. Louis[c]	P	8	8	0 (4)	0	7 (4)	2
Mont:	Helena[c]	P	5	5	0 (4)	0	3 (4)	5
Nebr:	Omaha[c]	P	6	6	0 (5)	0	0 (5)	1
Nev:	Las Vegas[c]	P	3	1	0 (4)	0	0 (4)	0

See footnotes at end of table.

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Table 3. Concentrations of radionuclides in milk for May 1970 and 12-month period June 1969 through May 1970—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average[c]	Monthly average[b]	12-month average[c]	Monthly average[b]	12-month average[c]
UNITED STATES—Continued								
N.H:	Manchester[e]	P	5	8	0 (4)	0	15(4)	10
N.J:	Trenton[e]	P	8	8	0 (4)	0	7 (4)	5
N. Mex:	Albuquerque[e]	P	2	3	0 (4)	0	0 (4)	0
N.Y:	Buffalo[e]	P	7	7	0 (5)	0	6 (5)	7
	New York City[e]	P	9	10	0 (4)	0	10 (4)	12
	Syracuse[e]	P	5	7	0 (4)	0	14 (4)	9
	Albany	P	9	4	0 (4)	0	(e) (4)	(e)
	Buffalo	P	(e)	(e)	0 (3)	0	(e) (3)	(e)
	Massena	P	7	6	0 (2)	0	26 (2)	(e)
	Newburg	P	12	6	0 (4)	0	(e) (4)	(e)
	New York City	P	11	7	0 (5)	0	(e) (5)	(e)
	Syracuse	P	4	3	0 (2)	0	(e) (2)	(e)
N.C:	Charlotte[e]	P	12	12	0 (4)	0	9 (4)	12
N. Dak:	Minot[e]	P	9	10	0 (4)	0	17 (4)	15
Ohio:	Cincinnati[e]	P	10	8	0 (4)	0	8 (4)	3
	Cleveland[e]	P	9	9	0 (5)	0	9 (5)	5
Oklahoma:	Oklahoma City[e]	P	7	7	0 (3)	0	8 (3)	8
	Oklahoma City	P	NS		NS		NS	
	Enid	P	NS		NS		NS	
	Tulsa	P	NS		NS		NS	
	Lawton	P	NS		NS		NS	
	Ardmore	P	NS		NS		NS	
Oreg:	Portland[e]	P	6	6	0 (5)	0	7 (5)	6
	Baker	P	4	3	0	0	0	0
	Coos Bay	P	10	5	0	0	21	12
	Eugene	P	2	2	0	0	0	6
	Medford	P	3	2	0	0	0	8
	Portland composite	P	4	4	0	0	10 (4)	6
	Portland local	P	7	5	0	0	8 (4)	9
	Redmond	R	4	2	0	0	0	3
	Tillamook	R	7	6	0	0	21	13
Pa:	Philadelphia[e]	P	9	9	0 (5)	0	10 (5)	5
	Pittsburgh[e]	P	11	11	0 (4)	0	12 (4)	8
	Dauphin	P	7	7	0	3	0	10
	Erie	P	8	10	0	6	12	24
	Philadelphia	P	6	8	0	4	0	10
	Pittsburgh	P	6	11	0	3	12	19
R.I:	Providence[e]	P	8	9	0 (4)	0	17 (4)	15
S.C:	Charleston[e]	P	10	10	0 (4)	0	21 (4)	22
S. Dak:	Rapid City[e]	P	6	8	0 (4)	0	0 (4)	3
Tenn:	Chattanooga[e]	P	10	9	0 (4)	0	7 (4)	12
	Memphis[e]	P	11	9	0 (4)	0	9 (4)	4
	Chattanooga	P	9	12	3 (4)	0	20 (4)	14
	Clinton	P	16	16	0	0	17	11
	Knoxville	P	11	10	0 (2)	0	13 (2)	6
	Nashville	P	9	8	0 (2)	0	7 (2)	7
	Fayetteville	P	15	12	0 (2)	0	10 (2)	14
Tex:	Austin[e]	P	3	2	0 (4)	0	0 (4)	3
	Dallas[e]	P	11	6	0 (4)	0	9 (4)	7
	Amarillo	R	NS	4	NS	0	NS	0
	Corpus Christi	R	3	4	0	0	0	2
	El Paso	R	4	2	0	0	0	0
	Fort Worth	R	NS	4	NS	0	NS	2
	Harlingen	R	NS	3	NS	0	NS	0
	Houston	R	NS	7	NS	0	NS	10
	Lubbock	R	5	4	0	0	0	0
	Midland	R	NS	2	NS	0	NS	0
	San Antonio	R	NS	4	NS	0	NS	0
	Texarkana	R	NS	10	NS	0	NS	0
	Tyler	R	13	9	0	0	0	5
	Uvalde	R	3	3	0	0	0	0
	Wichita Falls	R	13	9	0	0	0	0
Utah:	Salt Lake City[e]	P	4	4	0 (4)	0	0 (4)	2
Vt:	Burlington[e]	P	6	8	0 (4)	0	10 (4)	12
Va:	Norfolk[e]	P	9	10	0 (5)	0	10 (5)	8
Wash:	Seattle[e]	P	5	6	0 (4)	0	0 (4)	7
	Spokane[e]	P	6	6	0 (2)	0	0 (2)	3
	Benton County	R	0	0	0	0	0	7
	Franklin County	R	NS	2	NS	0	NS	3
	Sandpoint, Idaho	R	11	11	0	0	25	26
	Skagit County	R	5	6	0	0	17	13
W. Va:	Charleston[e]	P	9	9	0 (4)	0	6 (4)	5
Wisc:	Milwaukee[e]	P	6	7	0 (5)	0	10 (5)	10
Wyo:	Laramie[e]	P	4	5	0 (4)	0	.0 (4)	2
CANADA								
Alberta:	Calgary	P	(g)		(d)		23	18
	Edmonton	P	(g)		(d)		16	16
British Columbia:	Vancouver	P	(g)		(d)		27	29
Manitoba:	Winnipeg	P	(g)		(d)		29	21

See footnotes at end of table.

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Table 3. Concentrations of radionuclides in milk for May 1970 and 12-month period June 1969 through May 1970—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA—Continued								
New Brunswick:	Fredericton	P	(g)		(d)		20	19
Newfoundland:	St. Johns	P	(g)		(d)		35	35
Nova Scotia:	Halifax	P	(g)		(d)		21	21
Ontario:	Ft. William	P	(g)		(d)		30	29
	Ottawa	P	(g)		(d)		17	13
	Sault Ste. Marie	P	(g)		(d)		31	29
	Toronto	P	(g)		(d)		12	11
	Windsor	P	(g)		(d)		9	10
Quebec:	Montreal	P	(g)		(d)		16	17
	Quebec	P	(g)		(d)		21	25
Saskatchewan:	Regina	P	(g)		(d)		22	13
	Saskatoon	P	(g)		(d)		15	11
CENTRAL AND SOUTH AMERICA:								
Colombia:	Bogota	P	2	2	0	0	10	4
Chile:	Santiago	P	0	0	0	0	0	2
Ecuador:	Guayaquil	P	0	4	0	5	0	0
Jamaica:	Mandeville	P	4	4	0	0	60	86
Venezuela:	Caracas	P	2	2	0	0	0	0
Canal Zone:	Cristobal[c]	P	2	0	0 (4)	0	5 (4)	9
Puerto Rico:	San Juan[c]	P	5	3	0 (3)	0	7 (3)	7
PMN Network average[f]			8	7	0	0	8	8

[a] P, pasteurized milk. R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] PHS Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] Radionuclide analysis not routinely performed.

[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:

Iodine-131: Colorado—25 pCi/liter
Michigan—14 pCi/liter
Oregon—15 pCi/liter

Cesium-137: Colorado—25 pCi/liter
New York—20 pCi/liter
Oregon—15 pCi/liter

Strontium-90: New York—3 pCi/liter

[f] This entry gives the average radionuclide concentrations for the PHS Pasteurized Milk Network stations denoted by footnote c.

[g] Monthly samples were collected and composited for quarterly analysis of strontium-90.

NA, no analysis.
NS, no sample collected.

to May 1970. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89 and barium-140 data have been omitted from table 3 since levels at the great majority of the stations for May 1970 were below the respective practical reporting levels. Table 4 gives monthly averages for those stations at which strontium-89 was detected.

Iodine-131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower values reflected by the radiation protection guidance provided by the Federal Radiation Council (table 1), levels in milk for this radionuclide are of particular public health interest. In general, the practical reporting level for iodine-131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Table 4. Strontium-89 in milk, May 1970

Sampling location		Radionuclide concentration (pCi/liter)
Alaska:	Palmer (PMN)	6
Calif:	Del Norte (State)	19
	Humboldt (State)	8
	Shasta (State)	7
Ky:	Louisville (PMN)	11
La:	New Orleans (PMN)	6
Mo:	St. Louis (PMN)	7
N.Y:	Massena (State)	7(2)
Ore:	Portland (PMN)	7
Tex:	Dallas (PMN)	7
W. Va:	Charleston (PMN)	9

Strontium-90 monthly averages ranged from 0 to 25 pCi/liter in the United States for the month of May 1970, and the highest 12-month average was 20 pCi/liter (Del Norte, Calif.) representing 10.0 percent of the Federal Radiation Council radiation protection guide (table

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1). Cesium-137 monthly averages ranged from 0 to 53 pCi/liter in the United States for May 1970, and the highest 12-month average was 79 pCi/liter (Southeast Fla.), representing 2.2 percent of the value presented in this report using the recommendations given in the Federal Radiation Council reports. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (*12*) and Jamaica. Iodine-131 results for individual samples were all below the practical reporting level.

The Canadian Department of National Health and Welfare changed their analysis pattern in May 1970. Monthly samples will be collected and composited for quarterly analysis of strontium-90.

Acknowledgement

Appreciation is expressed to the personnel of the following health agencies who provide data for their milk surveillance networks:

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Division of Environmental Sanitation
California State Department of Health

Radiological Health Section
Division of Air, Occupational and
Radiation Hygiene
Colorado State Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiological Health Service
Division of Occupational Health
Michigan Department of Health

Radiation Protection Division
Canadian Department of National
Health and Welfare

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Health
Division of Environmental Health Services
New York State Department of Health

Division of Occupational and Radiological
Health
Environmental Health Services
Oklahoma State Department of Health

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Office of Air Quality Control
Division of Technical Services
Washington State Department of Health

REFERENCES

(1) CAMPBELL, J. E., G. K. MURTHY, A. S. GOLDIN, H. D. ROBINSON, C. P. STRAUB, F. J. WEBER and K. H. LEWIS. The occurrence of strontium-90, iodine-131, and other radionuclides in milk, May 1957 through April 1958. Amer J Public Health 49:225 (February 1959).
(2) Chart of the Nuclides, Ninth Edition revised to July 1966. Knolls Atomic Power Laboratory (November 1966).
(3) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Section I. Milk Surveillance. Radiol Health Data Rep 9:730–746 (December 1968).
(4) ROSENSTEIN, M. and A. S. GOLDIN. Statistical technics for quality control of environmental radioassay. Health Lab Sci 2:93 (April 1965).
(5) KNOWLES, F. Interlaboratory study of iodine-131, cesium-137, barium-140, strontium-89, and strontium-90 measurements in milk, July–September 1969. Technical experiment 69–MKAQ–2. Analytical Quality Control Service, Bureau of Radiological Health (October 1969).
(6) NEILL, R. H. and D. R. SNAVELY. State Health Department sampling criteria for surveillance of radioactivity in milk. Radiol Health Data Rep 8:621–627 (November 1967).
(7) ROBINSON, P. B. A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966. Radiol Health Data Rep 9:475–488 (September 1968).
(8) FEDERAL RADIATION COUNCIL. Background materials for the development of radiation protection standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 13, 1960).
(9) FEDERAL RADIATION COUNCIL. Background materials for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).
(10) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 5. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (July 1964).
(11) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, protective action guides for strontium-89, strontium-90, and cesium-137, Report No. 7. Superindent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1965).
(12) PORTER, C. R., C. R. PHILLIPS, M. W. CARTER, and B. KAHN. The cause of relatively high cesium-137 concentrations in Tampa, Florida, milk. Radioecological Concentration Processes, Proceedings of an International Symposium held in Stockholm, April 25-29, 1966. Pergamon Press, New York, N.Y. (1966) pp. 95–101.

Kansas Milk Network, January-December 1969

Radiation Control Section
Kansas State Health Department

The Radiation Control Section of the Kansas State Health Department maintains a program for analysis of pasteurized milk for strontium-89, strontium-90, and gamma-ray emitting radionuclides. Monthly milk samples are collected from six major consumption areas within Kansas. In addition, a sample is collected every other month in the Falls City, Nebr. area for the purpose of establishing baseline data to be used for environmental studies in connection with the commercial power reactor under construction at Brownville, Nebr. Brownville is located 22 miles north of the Kansas border. Figure 1 shows the various sampling sites. The Wichita and Kansas City samples are "split" samples which are analyzed by Kansas and the Public Health Service's Southwestern Radiological Health Laboratory (SWRHL).

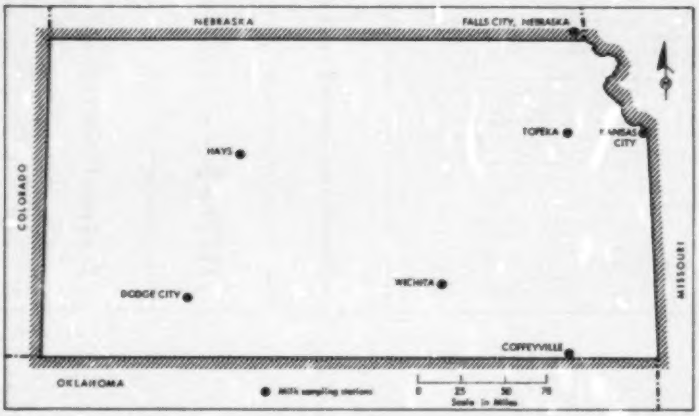

Figure 1. Kansas milk sampling stations

Table 1. Radionuclide and stable element concentration in Kansas pasteurized milk, 1969

Month	Location	Cesium-137 (pCi/liter)	Iodine-131 (pCi/liter)	Strontium-90 (pCi/liter)	Potassium-40 (pCi/liter)	Calcium (g/liter)
January	Dodge City	9	ND	6	1,121	1.1
	Coffeyville	13	6	9	997	1.2
	Hays	NS	NS	NS	NS	NS
	Kansas City	NS	NS	NS	NS	NS
	Falls City	9	1	2	1,150	1.1
	Topeka	9	4	6	993	1.2
	Wichita	NS	NS	NS	NS	NS
February	Dodge City	12	10	3	1,107	1.2
	Coffeyville	6	6	5	1,067	1.1
	Hays	3	3	4	1,103	1.2
	Kansas City	NS	NS	NS	NS	NS
	Falls City	NS	NS	NS	NS	NS
	Topeka	6	ND	5	1,042	1.1
	Wichita	NS	NS	NS	NS	NS
March	Dodge City	5	6	7	1,157	1.2
	Coffeyville	15	7	3	1,041	1.2
	Hays	NS	NS	NS	NS	NS
	Kansas City	NS	NS	NS	NS	NS
	Falls City	6	4	5	1,092	1.2
	Topeka	9	NS	12	958	1.2
	Wichita	NS	NS	NS	NS	NS
April	Dodge City	4	10	3	1,641	1.2
	Coffeyville	6	ND	4	1,050	1.1
	Hays	6	ND	2	1,038	1.2
	Kansas City	NS	NS	NS	NS	NS
	Falls City	NS	NS	NS	NS	NS
	Topeka	9	4	5	1,041	1.1
	Wichita	NS	NS	NS	NS	NS
May	Dodge City	4	ND	6	1,056	1.1
	Coffeyville	5	ND	9	976	1.1
	Hays	6	ND	5	1,028	1.1
	Kansas City	NS	NS	NS	NS	NS
	Falls City	7	ND	6	993	1.1
	Topeka	6	ND	11	930	1.1
	Wichita	NS	NS	NS	NS	NS
June	Dodge City	7	ND	11	913	1.1
	Coffeyville	7	8	17	1,011	1.1
	Hays	11	ND	9	982	1.0
	Kansas City	ND	ND	15	1,072	1.3
	Falls City	NS	NS	NS	NS	NS
	Topeka	6	3	15	1,008	1.0
	Wichita	12	ND	17	1,008	1.0
July	Dodge City	2	ND	14	1,203	1.1
	Coffeyville	10	ND	16	1,225	1.1
	Hays	13	ND	15	1,325	1.0
	Kansas City	1	ND	17	1,216	1.1
	Falls City	4	ND	18	1,304	1.1
	Topeka	7	ND	17	1,160	1.1
	Wichita	4	ND	14	1,304	1.0
August	Dodge City	8	ND	14	1,334	1.7
	Coffeyville	8	ND	12	1,287	1.0
	Hays	9	ND	15	1,250	1.0
	Kansas City	8	ND	12	1,275	1.3
	Falls City	NS	NS	NS	NS	NS
	Topeka	8	NS	17	1,267	1.0
	Wichita	8	ND	14	1,252	1.1
September	Dodge City	8	ND	8	1,344	1.1
	Coffeyville	1	ND	13	1,237	1.1
	Hays	8	10	14	1,261	1.1
	Kansas City	10	9	16	1,252	1.1
	Falls City	3	ND	19	1,200	1.1
	Topeka	6	ND	7	1,259	1.1
	Wichita	9	4	7	1,252	1.1
October	Dodge City	6	2	11	1,245	1.1
	Coffeyville	2	ND	13	1,171	1.1
	Hays	8	ND	7	1,179	1.2
	Kansas City	5	7	11	1,252	1.2
	Falls City	NS	NS	NS	NS	NS
	Topeka	8	2	13	1,212	1.1
	Wichita	6	2	11	1,244	1.1
November	Dodge City	8	6	14	1,208	1.1
	Coffeyville	9	7	13	1,297	1.1
	Hays	4	1	16	1,182	1.1
	Kansas City	6	9	21	1,276	1.1
	Falls City	3	ND	12	1,209	1.2
	Topeka	8	3	11	1,266	1.1
	Wichita	2	2	19	1,215	1.1
December	Dodge City	12	13	8	1,254	1.2
	Coffeyville	8	ND	11	1,208	1.1
	Hays	7	ND	9	1,197	1.1
	Kansas City	2	ND	9	1,163	1.1
	Falls City	NS	NS	NS	NS	NS
	Topeka	6	2	8	1,158	1.2

ND, nondetectable.
NS, no sample.

Analytical procedures

Each 3-1/2 liter sample is analyzed by gamma-ray scintillation spectrometry for barium-140, cesium-137, iodine-131, and potassium-40 (*1-2*). Strontium-89 and strontium-90 concentrations are determined radiochemically using ion exchange procedures (*3*). Chemical analyses for stable calcium have been made since 1968. Chemical analysis for potassium was begun in May 1970.

Results

Table I shows the stable element and radionuclide concentration in the Kansas pasteurized milk network for January-December 1969. No significant strontium-89 or barium-140 concentrations were found during this period except for the following barium-140 concentrations: September, Coffeyville, 11 pCi/liter; Kansas City, 16 pCi/liter; October, Hays, 11 pCi/liter; and December, Wichita, 14 pCi/liter.

REFERENCES

(*1*) KANSAS STATE DEPARTMENT OF HEALTH. Radiochemistry Laboratory Manual.

(*2*) PORTER, C. R., R. J. AUGUSTINE, J. MATUSEK, JR., and M. W. CARTER. Procedures for Determining Stable Nuclides in Environmental Samples, PHS Publication 999-RH-10. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (January 1965).

(*3*) PORTER, C. D., R. SCHNEIDER, P. ROBBINS, W. PERRY, and B. KAHN. Improved determinations of strontium-90 in milk by an ion-exchange method. Anal Chem 36:676-678 (March 1964).

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows.

Program	Period reported	Issue
California Diet Study	October–December 1968 and January–March 1969	May 1970
Connecticut Diet Study	July–December 1968 and January–June 1969	February 1970
Radionuclides in Institutional Diet Samples, *PHS*	October–December 1969 and annual summary 1969	August 1970
Strontium-90 in Tri-City Diets, *HASL*	June–December 1969	June 1970

SECTION II. WATER

The Public Health Service, the Federal Water Quality Administration and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

Water sampling program	Period reported	Issue
California	July–December 1968	August 1970
Minnesota	January–June 1969	January 1970
New York	January–June 1969	June 1970
North Carolina	January–December 1967	May 1969
Radiostrontium in Tap Water, *HASL*	January–December 1969	July 1970
Tritium Network	July–December 1969	July 1970
Washington	July 1967–June 1968	June 1969

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[1] Absence is taken to mean a negligible small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Supreintendent of Documents. U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Radioactivity in Kansas Surface Waters, January-December 1969

Kansas State Department of Health
Radiological Health Section

Levels of radioactivity in the surface waters of Kansas are monitored by the Kansas State Department of Health, Radiation Control Section, in cooperation with the Radiological Laboratory and Water Data Analysis Section. This surveillance program is important because of both the present and future potential use of Kansas surface waters for domestic, recreational, and industrial purposes.

Liter samples are collected every month at each location shown in figure 1. These samples are analyzed for gross alpha and beta radioactivity. Radioactivity in these waters consists of the natural radioactivity picked up by flowing streams and percolating ground water, radioactivity from sewage discharge into the streams, and some contribution by industrial waste. The final contributing factor to radioactivity content is fallout, particularly over large expanses of open water, such as reservoirs and lakes.

Analytical procedures

Radioactivity analyses are performed by the Kansas Radiological Health Laboratory. Measurements of gross alpha-plus-beta radioactivity in total solids are made with a windowless-gas-flow proportional counter. Each sample is evaporated on an aluminum planchet, dried at 250° C., and then counted. Specific radionuclide analyses are made by gamma spectroscopy or chemical separation.

Discussion

Table 1 shows the gross alpha and gross beta radioactivity in the total solids in Kansas surface waters from January through December 1969. These waters are used for domestic, industrial, and recreational purposes.

At the present time, there is only one surface water sampling station in western Kansas, at Dodge City. This is partly because of the scarcity of surface water in this region. Plans for the future include the development of at least five sampling points in the western portion of the State.

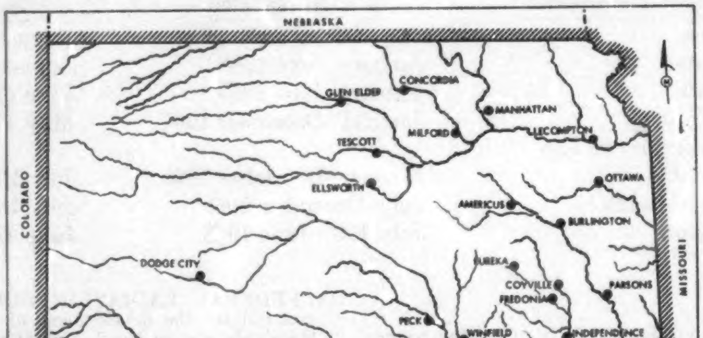
NEBRASKA
CONCORDIA
GLEN ELDER
MANHATTAN
MILFORD
LECOMPTON
TESCOTT
ELLSWORTH
OTTAWA
AMERICUS
BURLINGTON
COLORADO
DODGE CITY
EUREKA
COYVILLE
FREDONIA
PARSONS
MISSOURI
PECK
WINFIELD
INDEPENDENCE
ARKANSAS CITY
BAXTER SPRINGS
OKLAHOMA
● Water sampling stations
0 25 50 75
Scale in Miles

Figure 1. Kansas surface water sampling stations

Table 1. Gross radioactivity in Kansas surface waters, January–December 1969

Rivers	Sampling stations	Radioactivity concentration (pCi/liter)											
		January		February		March		April		May		June	
		Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
Arkansas	Arkansas City	ND	[a]7	[a]9	ND	[a]3	[a]53	ND	[a]10	[a]2	[a]40	ND	[a]10
	Dodge City	[a]18	20	[a]44	[a]65	[a]11	[a]34	[a]22	ND	[a]2	[a]60	[a]2	93
Big Blue	Manhattan	[a]6	[a]15	ND	[a]23	[a]1	36	[a]4	[a]14	[a]6	[a]25	[a]2	[a]20
Fall	Eureka	[a]11	[a]21	ND	[a]12	ND	[a]28	[a]2	[a]4	ND	[a]16	ND	35
	Fredonia	[a]2	[a]7	[a]4	[a]24	ND	[a]9	[a]10	[a]5	ND	[a]33	[a]2	[a]20
Kansas	Lecompton	NS	NS	ND	27	[a]3	[a]4	[a]3	[a]6	[a]9	[a]4	[a]10	[a]38
Marais Des Cygnes	Ottawa	[a]5	[a]15	[a]8	[a]26	[a]4	[a]31	NS	NS	NS	NS	NS	NS
Neosho	Americus	ND	ND	[a]2	[a]20	ND	[a]32	[a]1	ND	[a]8	[a]28	ND	[a]2
	Burlington	ND	[a]20	ND	[a]16	ND	ND	[a]1	[a]21	[a]6	15	NS	NS
	Parsons	[a]4	[a]14	ND	[a]16	ND	[a]5	ND	[a]15	[a]12	[a]18	ND	[a]20
Ninnescah	Peck	ND	[a]1	ND	[a]22	[a]1	[a]14	ND	ND	ND	[a]20	[a]7	ND
Republican	Concordia	[a]13	[a]18	NS	NS	[a]10	[a]26	[a]4	42	[a]6	[a]10	[a]7	[a]22
	Milford	ND	[a]32	NS	NS	[a]10	[a]33	[a]6	[a]15	ND	46	[a]1	[a]16
Saline	Tescott	[a]23	[a]36	ND	[a]30	[a]2	[a]30	[a]7	49	[a]12	57	[a]4	[a]20
Smoky Hill	Ellsworth	[a]2	31	[a]10	52	[a]10	[a]15	[a]9	[a]34	[a]6	[a]4	[a]3	[a]19
Solomon	Glenn Elder	[a]15	[a]9	[a]4	46	NS	NS	[a]7	[a]27	[a]5	46	ND	55
Spring	Baxter Springs	ND	[a]10	[a]4	[a]8	ND	[a]5	ND	[a]14	[a]2	[a]11	ND	[a]37
Verdigris	Coyville	[a]8	[a]18	ND	41	[a]3	[a]9	[a]1	ND	[a]1	[a]25	ND	[a]18
	Independence	[a]8	25	[a]22	[a]17	ND	[a]2	[a]9	[a]20	[a]5	[a]2	ND	[a]20
Walnut	Winfield	[a]2	[a]2	ND	[a]10	[a]2	[a]5	ND	[a]6	[a]7	[a]16	ND	[a]26

Table 1. Gross radioactivity in Kansas surface waters, January–December 1969—(Continued)

Rivers	Sampling stations	Radioactivity concentration (pCi/liter)											
		July		August		September		October		November		December	
		Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
Arkansas	Arkansas City	[a]30	54	6	[a]31	1	[a]46	[a]13	ND	[a]19	20	[a]11	ND
	Dodge City	[a]18	ND	[a]39	[a]31	[a]40	ND	6	75	[a]31	[a]70	[a]16	[a]81
Big Blue	Manhattan	NS	NS	[a]9	37	[a]4	[a]26	[a]4	[a]20	[a]1	35	24	5
Fall	Eureka	[a]3	[a]18	[a]5	[a]9	ND	ND	[a]1	[a]16	[a]6	[a]11	ND	39
	Fredonia	ND	[a]8	[a]4	[a]2	ND	ND	[a]1	[a]10	[a]5	[a]25	23	[a]12
Kansas	Lecompton	ND	[a]25	NS	NS	[a]3	[a]33	[a]13	[a]32	[a]4	[a]9	[a]3	[a]15
Marais Des Cygnes	Ottawa	[a]6	[a]14	NS	NS	[a]1	[a]28	[a]1	[a]23	[a]9	[a]34	[a]2	ND
Neosho	Americus	ND	38	3	34	NS	NS	NS	NS	NS	NS	NS	NS
	Burlington	NS	NS	NS	NS	NS	NS	NS	NS	[a]1	53	[a]1	[a]9
	Parsons	[a]3	[a]9	ND	[a]6	[a]2	[a]19	[a]1	[a]19	[a]4	[a]20	ND	[a]31
Ninnescah	Peck	[a]2	[a]9	ND	[a]14	[a]1	[a]9	ND	[a]24	[a]4	46	NS	NS
Republican	Concordia	NS	NS	[a]8	36	[a]13	47	[a]3	[a]22	[a]6	54	[a]5	35
	Milford	[a]2	[a]24	[a]5	[a]18	[a]10	[a]16	[a]2	[a]12	[a]8	51	NS	NS
Saline	Tescott	[a]15	[a]25	[a]32	[a]30	ND	[a]50	[a]17	[a]4	[a]4	[a]38	[a]1	[a]55
Smoky Hill	Ellsworth	[a]8	[a]35	[a]9	61	[a]3	ND	[a]2	ND	[a]12	[a]68	[a]6	[a]2
Solomon	Glenn Elder	[a]4	[a]18	[a]14	[a]22	[a]13	55	ND	[a]23	[a]2	[a]31	[a]6	[a]33
Spring	Baxter Springs	[a]2	ND	NS	NS	[a]2	ND	NS	NS	NS	NS	NS	NS
Verdigris	Coyville	ND	[a]23	[a]10	[a]2	NS	NS	[a]8	[a]2	[a]1	[a]11	ND	[a]9
	Independence	ND	[a]7	[a]5	[a]32	ND	[a]7	[a]8	[a]9	ND	[a]20	[a]2	[a]10
Walnut	Winfield	[a]2	[a]24	[a]13	[a]25	[a]3	[a]5	ND	[a]4	[a]7	[a]20	[a]9	[a]18

[a] When the counting rate of the sample is not equal to at least twice the 95-percent error, the value reported is not statistically significant but is the best available estimate.
NS, no sample.
ND, nondetectable.

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SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports*:

Network	Period	Issue
Fallout in the United States and Other Areas, *HASL*	January–June 1968	October 1969
Plutonium in Airborne Particulates and Precipitation, *PHS*	January–March 1969	August 1970

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1. Radiation Alert Network
May 1970

National Air Pollution Control Administration
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 73 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel. On January 1, 1970, the operation of the RAN was transferred from the Bureau of Radiological Health to the National Air Pollution Control Administration (NAPCA). This transfer was completed in May 1970.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate NAPCA officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Data Acquisition and Analysis Branch, Division of Air Quality Emission Data, NAPCA, Cincinnati, Ohio. A detailed description of the sampling and analytical procedures was presented in the April 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during May 1970. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting station.

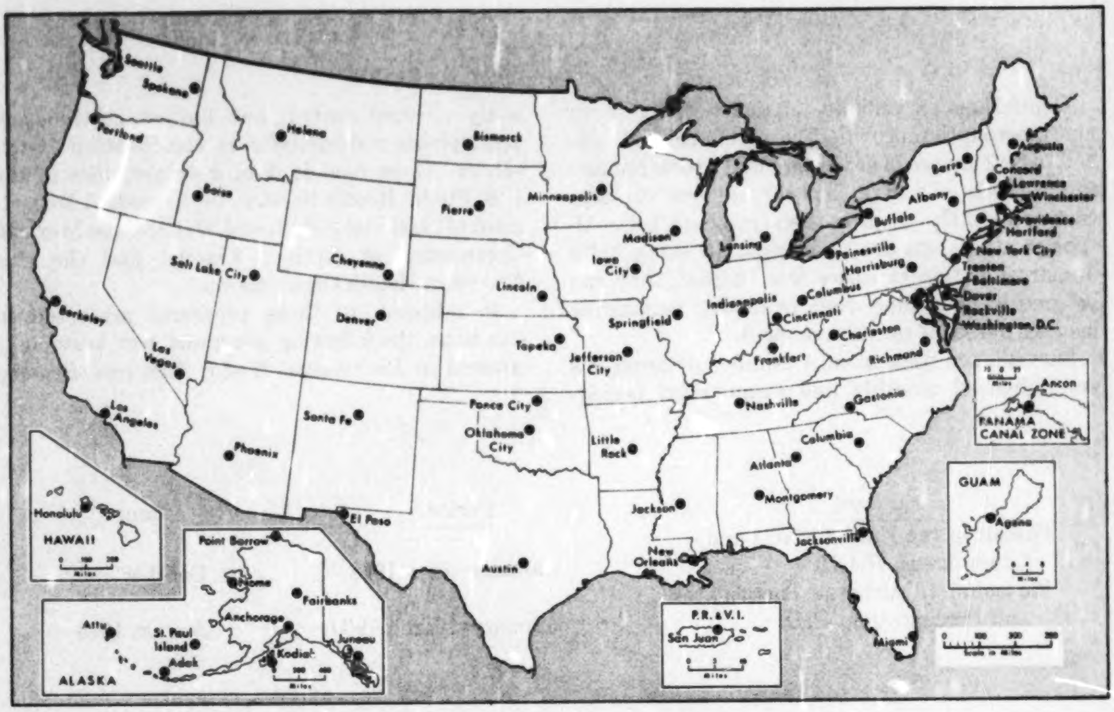
Seattle
Spokane
Portland
Helena
Bismarck
Boise
Pierre
Minneapolis
Salt Lake City
Cheyenne
Lincoln
Berkeley
Denver
Las Vegas
Topeka
Los Angeles
Santa Fe
Ponca City
Oklahoma City
Phoenix
El Paso
Austin
Honolulu
HAWAII
Point Barrow
Nome
Fairbanks
Anchorage
Attu
St. Paul Island
Adak
Kodiak
Juneau
ALASKA
Madison
Lansing
Iowa City
Springfield
Jefferson City
Indianapolis
Columbus
Cincinnati
Charleston
Frankfort
Richmond
Painesville
Harrisburg
Buffalo
Albany
Barre
Augusta
Concord
Lawrence
Winchester
Providence
Hartford
New York City
Trenton
Baltimore
Dover
Rockville
Washington, D.C.
Nashville
Gastonia
Little Rock
Columbia
Atlanta
Montgomery
Jackson
New Orleans
Jacksonville
Miami
Ancon
PANAMA CANAL ZONE
GUAM
Agana
P.R. & V.I.
San Juan
Scale in Miles
Miles

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, May 1970

Station location	Air surveillance				Last profile in RHD&R	Precipitation				
	Number of samples	Gross beta radioactivity (pCi/m^3)				Number of samples	Total depth (mm)	Field estimation of deposition		
		Maximum	Minimum	Average[a]				Number of samples	Depth (mm)	Total deposition (nCi/m^2)
Ala: Montgomery	22	8	1	4	Dec 69	1	11	1	11	27
Alaska: Adak	(b)				Oct 70	(c)				
Anchorage	16	0	0	0	June 70	(c)				
Attu Island	16	0	0	0	Jan 70	(c)				
Fairbanks	16	2	0	1	July 70	3	13	3	13	8
Juneau	(b)				Aug 70	(c)				
Kodiak	1	0	0	0	Sept 70	(c)				
Nome	31	2	0	1	Mar 70	(c)				
Point Barrow	31	0	0	0	Feb 70	(c)				
St. Paul Island	(b)				Apr 70	(c)				
Ariz: Phoenix	11	4	2	3	Aug 70	(c)				
Ark: Little Rock	10	4	1	2	June 70	(c)				
Calif: Berkeley	21	1	0	0	Sept 70	(c)				
Los Angeles	21	5	0	1	Mar 70	(c)				
C.Z: Ancon	15	0	0	0	Sept 70	(c)				
Colo: Denver	21	7	1	5	Sept 70	2	11	(d)		
Conn: Hartford	20	2	0	1	July 70	7	64	7	64	11
Del: Dover	20	1	0	1	May 70	(c)				
D.C: Washington	24	1	0	1	Feb 70	(c)				
Fla: Jacksonville	20	2	0	1	June 70	2	42	2	42	1
Miami	19	1	0	0	July 70	4	108	3	58	0
Ga: Atlanta	21	2	1	1	Apr 70	(c)				
Guam: Agana	(b)				May 70	(c)				
Hawaii: Honolulu	26	1	0	1	Jan 70	2	11	(d)		
Idaho: Boise	19	4	1	2	Jan 70	4	25	4	25	6
Ill: Springfield	19	5	1	2	Feb 70	(c)				
Ind: Indianapolis	(b)				Apr 70	(c)				
Iowa: Iowa City	14	4	0	2	Sept 70	5	116	5	116	14
Kans: Topeka	20	4	1	2	June 70	5	68	5	68	4
Ky: Frankfort	10	3	1	1	Feb 70	(c)				
La: New Orleans	16	1	0	1	Feb 70	6	121	(d)		
Maine: Augusta	20	2	0	1	Aug 70	9	278	9	278	0
Md: Baltimore	20	1	0	1	July 70	4	34	4	34	13
Rockville	17	3	0	1	Jan 70	(c)				
Mass: Lawrence	19	1	0	1	Sept 70	4	82	4	82	1
Winchester	19	2	0	1	Dec 69	4	82	4	82	0
Mich: Lansing	20	2	0	1	Jan 70	8	71	8	71	10
Minn: Minneapolis	21	4	0	1	May 70	8	148	8	148	37
Miss: Jackson	18	3	0	1	Aug 70	1	71	1	71	0
Mo: Jefferson City	20	3	0	1	Apr 70	8	205	8	205	4
Mont: Helena	18	3	0	1	Dec 69	3	17	3	17	0
Nebr: Lincoln	16	6	2	4	Apr 70	4	81	4	81	43
Nev: Las Vegas	15	3	1	2	July 70	(c)				
N.H: Concord	(b)				Feb 70	(c)				
N.J: Trenton	19	3	0	1	Aug 70	7	92	7	92	15
N. Mex: Santa Fe	11	3	0	2	Dec 69	1	7	1	7	0
N.Y: Albany	5	1	0	1	Apr 70	3	22	3	22	6
Buffalo	19	2	0	1	Sept 70	(c)				
New York City	(b)				Dec 69	(c)				
N.C: Gastonia	17	9	2	5	Sept 70	2	36	(d)		
N. Dak: Bismarck	21	3	0	1	Feb 70	8	57	8	57	3
Ohio: Cincinnati	(b)				May 70	(c)				
Columbus	4	3	0	2	Aug 70	(c)				
Painesville	16	2	1	1	July 70	8	71	8	71	28
Okla: Oklahoma City	(b)				Jan 70	(c)				
Punca City	19	3	0	2	July 70	2	19	2	19	0
Ore: Portland	19	1	0	0	Apr 70	5	37	5	37	2
Pa: Harrisburg	14	2	0	1	Apr 70	1	20	1	20	2
P.R: San Juan	(b)				Aug 70	(c)				
R.I: Providence	20	2	0	1	Jan 70	(c)				
S.C: Columbia	16	3	0	1	Dec 69	3	86	3	86	1
S. Dak: Pierre	15	6	1	3	Aug 70	(c)				
Tenn: Nashville	20	3	0	1	Jan 70	3	80	3	80	15
Tex: Austin	14	4	1	2	May 70	(c)				
El Paso	(b)				Feb 70	(c)				
Utah: Salt Lake City	31	3	0	2	Mar 70	7	35	7	35	4
Vt: Barre	19	3	0	1	June 70	7	66	7	66	8
Va: Richmond	21	1	0	1	June 70	5	64	5	64	10
Wash: Seattle	24	1	0	0	June 70	4	17	(d)		
Spokane	20	2	0	2	May 70	(c)				
W. Va: Charleston	19	3	0	2	Dec 69	4	48	4	48	5
Wisc: Madison	21	3	0	1	June 70	8	79	8	79	16
Wyo: Cheyenne	20	8	1	3	July 70	3	40	3	40	7
Network summary	1,127	9	0	1		4	65	5	67	9

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.

[b] No report received. (Air samples received without field estimate data are not considered by the data program.)

[c] No precipitation sample collected.

[d] This station is part of the plutonium in precipitation network. No gross beta measurements are done.

[e] Samples were collected but no field estimates were received.

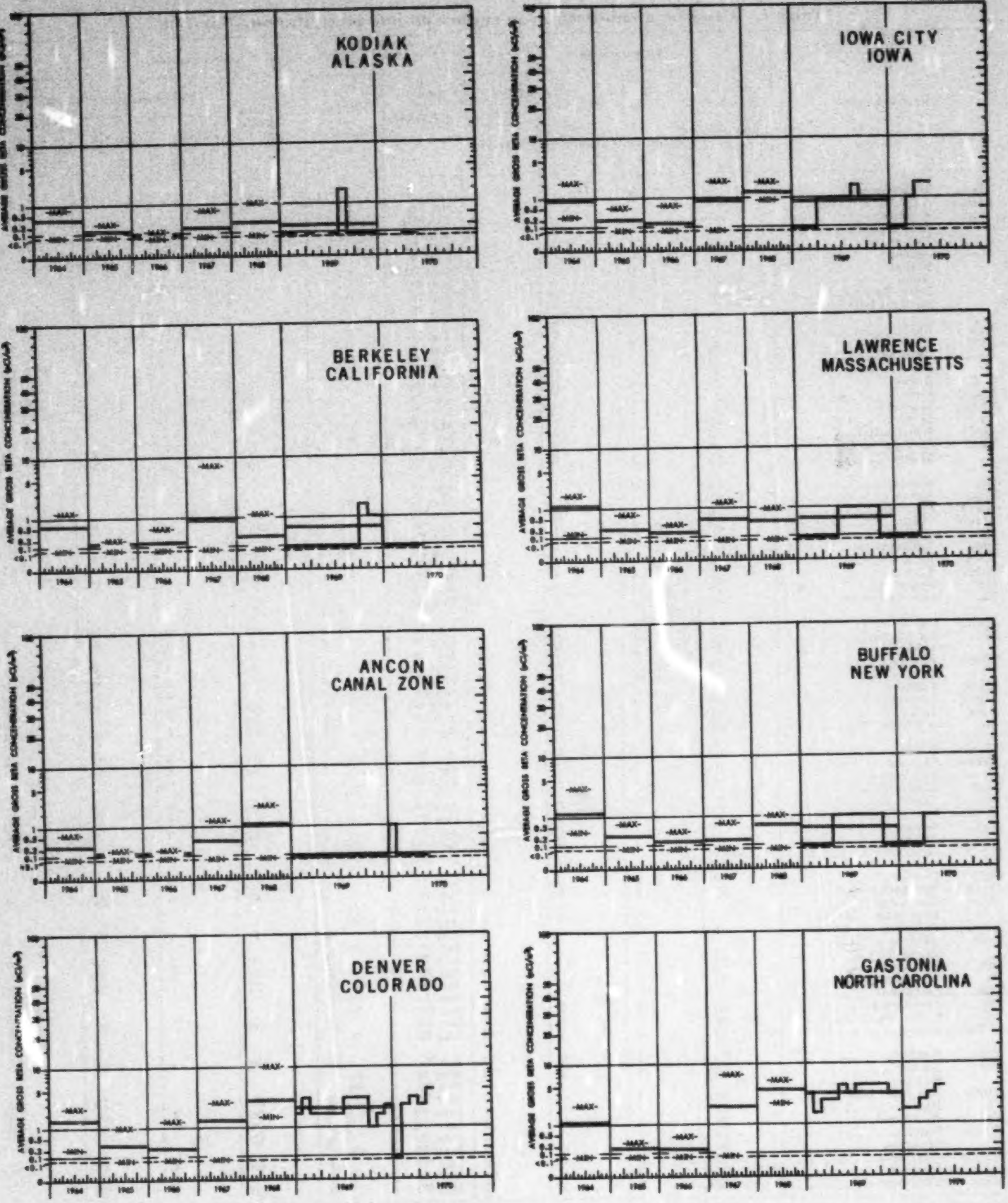

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1964–May 1970

2. Canadian Air and Precipitation Monitoring Program,[1] May 1970

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for May 1970 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, May 1970

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	31	1.6	0.1	0.3	60	1.3
Coral Harbour	31	.2	.1	.1	110	.8
Edmonton	30	.6	.1	.3	222	3.3
Ft. Churchill	29	.3	.1	.2	299	2.9
Fredericton	29	.9	.0	.3	91	8.4
Goose Bay	30	.5	.0	.1	50	3.9
Halifax	18	[illegible]	.0	.2	104	8.8
Inuvik	31	.1	.0	.1	177	2.6
Montreal	30	1.0	.1	.4	142	7.4
Moosonee	30	.9	.0	.3	77	3.9
Ottawa	31	.7	.1	.3	57	4.5
Quebec	31	.5	.0	.3	35	5.8
Regina	31	.6	.1	.3	136	6.9
Resolute	30	.2	.0	.2	75	.1
St. John's, Nfld	28	.5	.0	.2	19	2.1
Saskatoon	31	.6	.1	.3	313	4.1
Sault Ste. Marie	30	.6	.0	.3	50	10.4
Thunder Bay	29	.5	.0	.2	110	15.8
Toronto	31	.8	.0	.3	119	6.6
Vancouver	31	.5	.1	.2	110	2.9
Whitehorse	31	.3	.0	.1	130	3.1
Windsor	31	.6	.0	.3	20	1.7
Winnipeg	31	.6	.0	.3	185	16.0
Yellowknife	31	.5	.1	.2	25	.3
Network summary	716	1.6	0.0	0.3	115	5.2

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[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

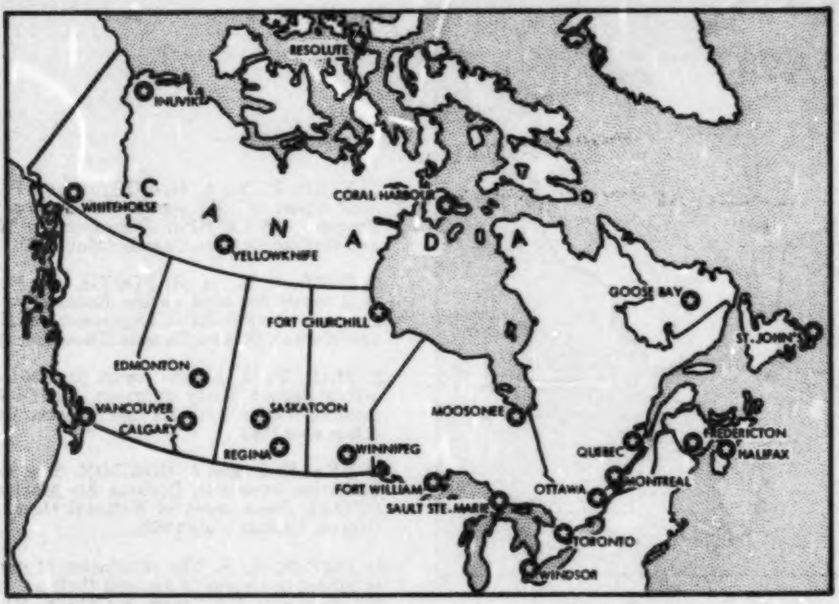
RESOLUTE
INUVIK
WHITEHORSE
C A N A D A
CORAL HARBOUR
YELLOWKNIFE
GOOSE BAY
FORT CHURCHILL
ST. JOHN'S
EDMONTON
SASKATOON
VANCOUVER
CALGARY
REGINA
WINNIPEG
MOOSONEE
FREDERICTON
HALIFAX
QUEBEC
MONTREAL
OTTAWA
FORT WILLIAM
SAULT STE. MARIE
TORONTO
WINDSOR

Figure 3. Canadian air and precipitation sampling stations

3. Pan American Air Sampling Program
May 1970

Pan American Health Organization and *U.S. Public Health Service*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 4. Analytical techniques were described in the January 1968 issue of *Radiological Health Data and Reports*. The May 1970 air monitoring results from the participating countries are given in table 3.

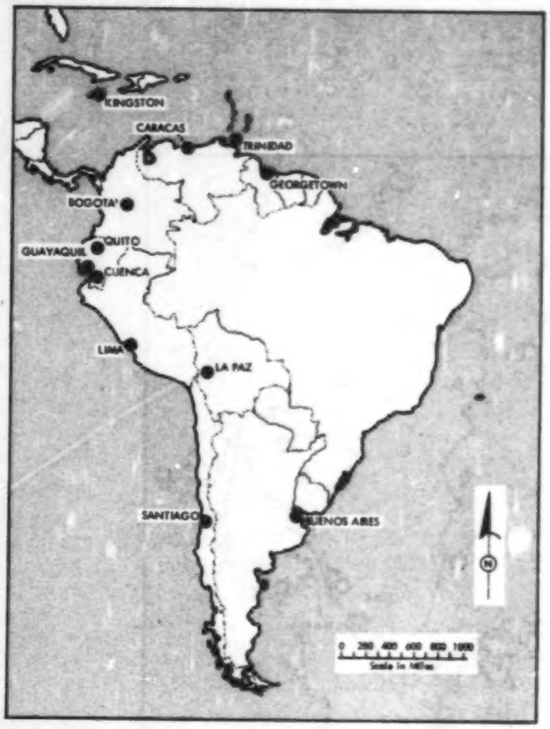

Figure 4. Pan American Air Sampling Program stations

Table 3. Summary of gross beta radioactivity in Pan American surface air, May 1970

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average[a]
Argentina:	Buenos Aires	NS	NS	NS	NS
Bolivia:	La Paz	NS	NS	NS	NS
Chile:	Santiago	19	0.14	0.02	0.05
Colombia:	Bogota	28	.12	.00	.03
Ecuador:	Cuenca	NS	NS	NS	NS
	Guayaquil	23	.07	.01	.02
	Quito	NS	NS	NS	NS
Guyana:	Georgetown	1	.22	.22	.22
Jamaica:	Kingston	NS	NS	NS	NS
Peru:	Lima	29	.06	.01	.03
Venezuela:	Caracas	26	.69	.00	.30
West Indies:	Trinidad	([b])	—	—	—
Pan American summary		126	0.69	0.00	0.09

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.
[b] Motor failure.
NS, no sample.

REFERENCES

(1) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW-RP-3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(2) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNRW-RP-3. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(3) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW-RP-5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(4) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD-11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(5) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD-21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

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SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Strontium-90 in Human Bone, October-December 1969[1]

Bureau of Radiological Health
U.S. Public Health Service

To obtain data on the concentration of strontium-90 in man by age and geographical region, the Public Health Service began collecting human bone specimens in late 1961. Analyses of selected samples of people in older-age groups have shown their bone strontium-90 content to be low and age-independent (*1*). Consequently, the target population includes children and young adults up to 25 years of age.

Although a few samples come from living persons as a result of surgical procedures, the majority are obtained post mortem. In the latter case, the specimens are limited to accident victims or persons who have died of an acute disease process that was not likely to impair bone metabolism. For analytical purposes, a sample of at least 100 grams of wet bone is desired. Generally, this amount is readily available from older children, but it presents some difficulties from the standpoint of infants and children under 5 years of age. Most specimens received to date have been vertebrae and ribs.

Laboratory procedures

The bones are analyzed at the Northeastern Radiological Health Laboratory of the Bureau of Radiological Health, at Winchester, Mass. Sample collection and preparation are explained

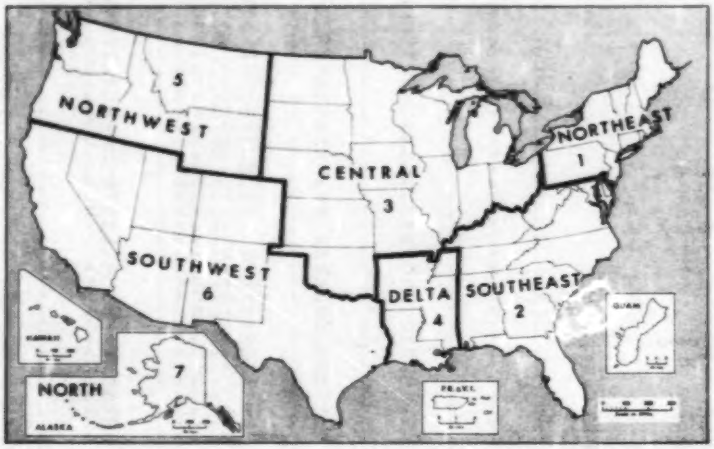

Figure 1. Geographical regions for human bone sampling

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[1] Period during which death or surgical procedure occurred.

Table 1. Strontium-90 in human bone, October–December 1969

Bone region and State	Bone type	Age[b] (years)	Sex	Strontium-90 concentration[a] (pCi/kg bone)	Calcium concentration (g/kg bone)	Sr/Ca (pCi/g)
Northeast:						
New York	V	9	M	57.4± 6.8	38.6	1.49
New Jersey	V	10	M	67.0± 8.0	36.2	1.85
New York	V	10	M	36.1± 7.9	27.1	1.33
	V	12	M	75.4± 8.7	52.6	1.43
	V	12	M	59.6± 7.0	36.3	1.64
	V	13	F	54.1± 5.9	31.2	1.73
	V	14	F	63.2±10.0	45.6	1.38
Rhode Island	S	15	M	47.8± 4.4	16.7	2.86
New York	V	18	M	73.9± 7.7	28.2	2.62
	V	20	F	93.9±10.0	55.2	1.70
	V	21	F	104.0± 8.8	57.5	1.80
	V	23	M	105.0±13.0	65.7	1.59
	V	23	M	44.7± 7.3	33.1	1.35
	V	24	M	53.5± 7.7	32.2	1.66
Rhode Island	S	25	M	12.2± 2.2	11.0	1.10
Southeast:						
North Carolina	V	7	M	37.4± 5.3	26.5	1.41
South Carolina	V	7	M	88.3± 8.5	30.2	2.92
	V	7	F	77.1±10.0	26.7	2.88
	V	14	M	118.0±13.0	45.7	2.58
Maryland	V	14	M	172.0±15.0	72.3	2.37
South Carolina	V	16	M	148.0±12.0	48.5	3.05
Maryland	V	17	F	90.9± 9.5	47.0	1.93
Georgia	V	17	F	88.5±10.0	44.4	1.99
Maryland	V	18	F	89.3±13.0	67.6	1.32
	V	18	F	130.0±12.0	46.2	2.81
South Carolina	V	18	F	102.0± 9.5	50.7	2.01
Maryland	V	18	M	80.9± 9.2	52.2	1.54
	V	18	M	99.6± 9.0	54.8	1.81
	V	19	F	115.0±12.0	54.3	2.11
	V	19	F	41.7± 7.3	40.6	1.02
South Carolina	V	19	M	160.0±12.0	53.5	2.99
Maryland	V	20	M	126.0±12.0	53.2	2.36
	V	20	M	71.0± 9.9	50.9	1.39
	V	20	M	118.0±12.0	56.1	2.10
	V	20	F	55.9± 7.6	40.8	1.37
South Carolina	V	21	M	63.6± 8.9	40.4	1.57
Maryland	V	21	M	80.7±10.0	52.8	1.52
	V	22	M	87.4± 8.6	44.2	1.97
	V	22	M	82.2± 9.1	60.2	1.36
	V	23	M	129.0±11.0	67.4	1.91
	V	23	M	73.4± 7.7	43.6	1.68
Tennessee	V	25	M	31.7± 6.9	43.6	.72
Central:						
Ohio	V	0	M	153.0±14.0	66.8	2.29
Wisconsin	V	2	F	47.4± 7.1	28.0	1.69
Iowa	V	3	F	36.6± 6.0	23.7	1.54
Wisconsin	V	3	F	116.0±12.0	55.0	2.10
	V	4	M	55.3± 7.9	28.5	1.94
Ohio	V	8	M	79.1±10.0	51.1	1.54
Wisconsin	V	8	F	82.3± 8.6	34.0	2.42
Ohio	V	10	M	99.7±10.0	38.2	2.60
	V	11	F	81.6± 8.7	51.3	1.59
	V	13	F	138.0±13.0	59.8	2.30
	V	14	M	72.8± 7.9	39.2	1.85
Michigan	V	15	M	145.0±15.0	62.5	2.32
Ohio	V	15	F	107.0±13.0	62.0	1.72
	V	15	M	84.7± 9.7	56.8	1.49
	V	16	F	109.0±11.0	56.0	1.94
Michigan	V	16	M	192.0±15.0	65.5	2.93
Ohio	V	17	M	110.0± 9.5	47.3	2.32
	V	17	F	95.9±12.0	59.7	1.60
	V	18	M	162.0±14.0	60.7	2.66
	V	18	M	242.0±18.0	61.0	3.96
	V	18	M	77.6± 8.7	51.8	1.49
Minnesota	V	18	F	73.6± 7.7	50.0	1.47
Ohio	V	18	M	115.0±13.0	62.4	1.84
	V	19	M	146.0±10.0	51.3	2.84
	V	19	M	209.0±16.0	63.8	3.27
Minnesota	V	19	F	70.4± 8.8	46.2	1.52
Ohio	V	20	M	72.3± 9.8	53.1	1.36
	V	21	M	94.3± 9.1	56.4	1.67
	V	21	M	95.4±11.0	60.8	1.56
	V	21	M	152.0±15.0	76.8	1.97
	V	21	M	101.0±27.0	51.3	1.96
	V	22	M	130.0±12.0	66.0	2.04
	V	22	M	97.5±12.0	63.7	1.53
Minnesota	V	22	M	62.9± 8.6	45.9	1.37
Ohio	V	22	M	82.3±11.0	59.9	1.37
	V	23	M	91.0±12.0	61.2	1.48
	V	23	M	89.7±14.0	61.0	1.47
	V	23	F	64.7± 9.7	52.8	1.22
Michigan	V	24	M	102.0± 9.1	63.3	1.61
Ohio	V	24	M	83.7±11.0	53.5	1.56
Michigan	V	25	F	95.0± 8.6	49.8	1.90

See footnotes at end of table.

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Table 1. Strontium-90 in human bone, October–December 1969—Continued

Bone region and State	Bone type	Age (years)	Sex	Strontium-90 concentration (pCi/kg bone)	Calcium concentration (g/kg bone)	Sr/Ca (pCi/g)
Delta:						
Louisiana	V	9	F	103.0± 8.1	41.1	2.50
	V	15	M	138.0±13.0	50.2	2.74
	V	20	M	92.4±13.0	48.5	1.90
	V	20	F	96.0± 8.0	60.9	1.57
	V	25	M	85.8± 7.0	52.0	1.65
Northwest:						
Oregon	V	0	M	83.6± 9.9	49.6	1.69
	V	11	M	79.3± 6.9	36.9	2.14
Washington	V	16	M	126.0±10.0	40.4	3.11
Oregon	V	16	M	57.4± 6.3	43.4	1.32
	V	17	M	128.0±11.0	54.0	2.37
	V	18	M	71.9± 9.5	44.3	1.62
	V	19	M	91.3±11.0	38.5	2.37
	V	20	M	71.2± 9.7	47.8	1.49
	V	21	M	81.2±10.0	50.1	1.62
	V	23	F	52.0± 6.3	50.1	1.08
	V	24	F	39.1± 5.5	41.5	.94
Southwest:						
Colorado	V	21	M	64.5± 8.2	47.7	1.35
	V	21	M	18.5± 7.5	46.2	.40
	V	23	M	72.9± 9.9	62.0	1.17
	V	23	M	74.5± 8.5	53.6	1.38
North:						
Alaska	V	0	F	20.1± 8.9	13.7	1.46
	V	9	F	70.2± 5.6	29.3	2.30
	V	12	M	31.4± 5.1	22.6	1.38

[a] Type of bone, V, vertebrae; R, rib; S, sternum; T, tibia; F, femur.
[b] Age given as of last birthday prior to death.
[c] Two-sigma counting error.

elsewhere (*2*). Strontium-90 is measured by tributyl phosphate extraction of its yttrium daughter, which is precipitated as an oxalate. The strontium-90 content is then calculated (*3*) from the yttrium-90 activity. For the purpose of maintaining analytical reproducibility, "blind" duplicate analyses are performed on 10 to 20 percent of the samples.

The analytical results for strontium-90 in individual bones from persons dying during the fourth quarter (October–December) of 1969 are presented in table 1 in order of increasing age within each geographical region. These regions are indicated in figure 1. Reported values are given in picocuries of strontium-90 per kilogram of bone (as a rough indication of dose) and per gram of calcium (for comparison with other data and for purposes of model development). Two-sigma counting errors are reported for the bone concentration.

Following the pattern of earlier reports, subsequent articles will continue to provide interpretation of the data at appropriate stages in the program (*2–6*).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–March 1969	March 1970
April–June 1969	May 1970
July–September 1969	June 1970

REFERENCES

(*1*) RIVERA, J. Strontium-90 in human vertebrae, 1962–1963. Radiol Health Data 5:511–513 (October 1964).

(*2*) WEISS, E. S., W. H. LAND, K. H. FALTER, and R. M. HALLISEY. Strontium-90 content of human bones, 1961–1963. Radiol Health Data 5:231–239 (May 1964).

(*3*) PUBLIC HEALTH SERVICE, NORTHEASTERN RADIOLOGICAL HEALTH LABORATORY. Analysis of environmental samples, chemical and radiochemical procedures, NERHL 64-1. Northeastern Radiological Health Laboratory, Winchester, Mass. (April 1964).

(*4*) GAFFNEY, G. W., R. M. HALLISEY, M. S. MILLER, and A. S. GOLDIN. Strontium-90 in human bone, 1962–1963. Radiol Health Data 5:620–628 (December 1964).

(*5*) HALLISEY, R. M., and M. A. WALL. Strontium-90 in human bone, 1964–1965. Radiol Health Data Rep 8:415–419 (August 1967).

(*6*) BARATTA, E. J., E. S. FERRI, and M. A. WALL. Strontium-90 in human bones in the United States, 1962–1966. Radiol Health Data Rep 11: 183–186 (April 1970).

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Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for the Bettis Atomic Power Laboratory, Los Alamos Scientific Laboratory and the Paducah Plant.

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[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

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1. Bettis Atomic Power Laboratory[2]
January–December 1969

Westinghouse Electric Corporation
Pittsburgh, Pa.

The Bettis Atomic Power Laboratory (BAPL), operated for the Atomic Energy Commission by the Westinghouse Electric Corporation, was established in 1949 to conduct research and development operations related to naval atomic propulsion systems and to the central station power reactor at Shippingport, Pa. Routine environmental monitoring data from the sampling locations shown in figure 1 show no significant contribution from laboratory operations to environmental radioactivity levels.

Gaseous radioactive waste

The release of gaseous radioactive waste is monitored by continuous air sampling to assure compliance with laboratory regulations. The stack gas limits for the laboratory are based on the 168-hour nonoccupational maximum permissible concentrations in air as specified in AEC Manual Chapter 0524. At no time during 1969 did the concentration of stack releases exceed the required limits. The general public outside the boundary of the laboratory was not exposed to radiation above normal background levels as a result of operations at Bettis.

Total gaseous radioactivity released to the environment during 1969 was 1.88 mCi alpha and less than 189 mCi beta-gamma. Due to an increased volume of air discharged, the total radioactivity was greater than last year's quantities; the average concentration of radioactivity, however, remained the same.

Liquid radioactive waste

Radioactive liquids generated in the main laboratory and critical facility areas are collected in retention tanks and sampled for radioanalysis. The laboratory discharge limit of 2,000 pCi/liter is in compliance with AEC Manual Chapter 0524. If radioactivity of liquid wastes is greater than the discharge limit, the water is processed by ion exchange or evaporation. Water less than the discharge limit is released to the storm sewer and diluted with laboratory coolant water, process water, and surface runoff water. This plant effluent is discharged from laboratory property at the three locations shown in figure 1. A composite of the main laboratory effluent released at location 1 is collected and analyzed weekly for gross radioactivity. Critical facility effluent suitable for release is discharged at locations 2 and 3.

The plant effluent water analysis data is summarized in table 1. This shows that the average concentration of the laboratory effluent water is well below the discharge limit of 2,000 pCi/liter. Total radioactivity discharged from Bettis Laboratory during 1969 was 20.3 millicuries which was significantly less than the 90.3 millicuries released during 1968.

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[2] Summarized from "Bettis Atomic Power Laboratory, Environmental Monitoring Report, Calendar Year 1969" (WAPD-CL(RA)E-109).

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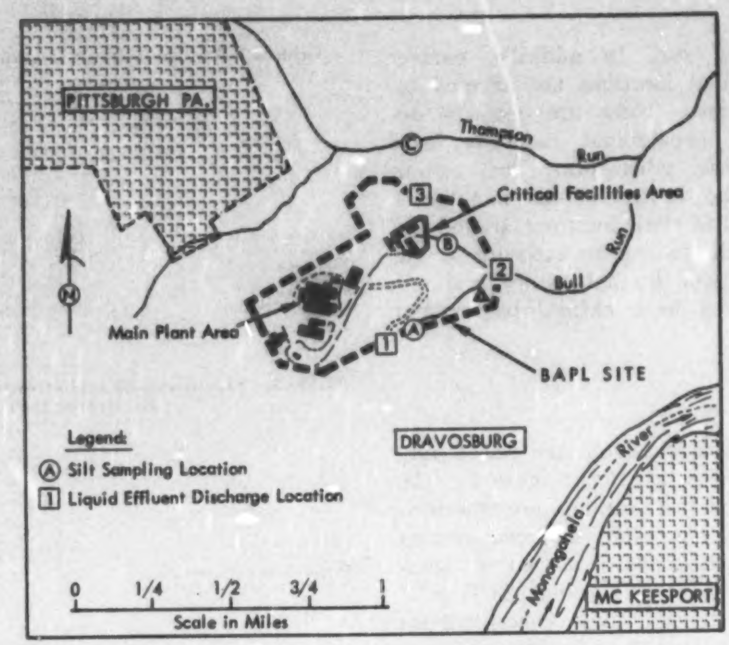
PITTSBURGH PA.
Thompson
Run
Critical Facilities Area
Bull
Run
Main Plant Area
BAPL SITE
N
DRAVOSBURG
River
Monongahela
MC KEESPORT
Legend:
Ⓐ Silt Sampling Location
1 Liquid Effluent Discharge Location
0
1/4
1/2
3/4
1
Scale in Miles
A
B
C
1
2
3

Figure 1. Bettis Atomic Power Laboratory sampling stations

Table 1. Average concentration of radioactivity in the Bettis Laboratory liquid effluent, January–December 1969[a]

Month 1969	Main laboratory			Critical facility		
	Gross radioactivity (pCi/liter)		Volume (10^6 gallons)	Gross radioactivity (pCi/liter)		Volume (10^3 gallons)
	Beta-gamma	Alpha		Beta-gamma	Alpha[b]	
January–March	47	5.5	36.4	1,400	<240	0.63
April–June	21	2.4	44.8	1,100	<240	3.7
July–September	21	2.4	40.4	1,200	350	18.0
October–December	25	13.0	38.1	—	—	0
Summary	28	5.7	159.7	1,200	330	22.33

[a] Discharge limit 2,000 pCi/liter gross radioactivity. The criteial facility effluent is just monitored process water whereas the main laboratory effluent inclubes the complete storm sewer flow.

[b] Minimum detectable level for alpha radioactivity for the analytical technique used is 240 pCi/liter.

The average concentrations of gross beta-gamma radioactivity in the main laboratory liquid effluent during 1969 was 28 pCi/liter. This was lower than the average concentration of 120 pCi/liter observed for the year 1968.

Average radioactivity in liquid waste effluent from the critical facility operations during 1969 were: alpha radioactiviy, <330 pCi/liter; beta-gamma radioactivity, 1.2 nCi/liter. Comparable values for 1968 were 610 pCi/liter for alpha radioactivity and 1.00 nCi/liter for beta-gamma radioactivity.

Background monitoring stations

Background beta-gamma radiation levels were continuously monitored and recorded at 34 film badge monitoring stations located along the perimeter fence of the laboratory which lies within the controlled confines of the Bettis Atomic

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Power Laboratory site. In addition, control badges are placed at locations not affected by laboratory operations. These are used to determine the net background radiation level contributed by the laboratory. The results obtained from the environmental monitoring film badges posted at these locations around the laboratory show that radiation exposure to the general public outside the laboratory was not above that received from natural background radiation levels.

Stream silt

Stream silt samples were collected periodically at the three discharge locations (figure 1). The results of analysis of these samples are presented in table 2. The average alpha and beta-gamma radioactivity concentrations of stream silt samples for 1969 were 17.86 pCi/g and 123.95 pCi/g, respectively. Although these concentrations represent an increase over those for 1968, they are consistent with concentrations detected in previous years.

Semiannual analyses for strontium-89 and strontium-90 were obtained for composites of silt samples. Table 3 presents the results of these analyses for samples collected during 1969.

Table 2. Radioactivity in stream silt, Bettis, 1969

Location	Number of samples	Radioactivity (pCi/g)			
		Alpha		Beta-gamma	
		Range	Average	Range	Average
Bull Run Stream	20	<11-70	20.5	30-436	187
C-Area Stream	10	<11-27	14.1	18-83	51
Thompson Run Stream	10	<11-33	15.8	41-116	71
Streets Run (Control Stream)	6	7-26	16.2	32-124	73

Table 3. Strontium-89 and strontium-90 in stream silt, Bettis, 1969

Location	Concentration (pCi/g of silt)	
	Strontium-89	Strontium-90
Bull Run Stream	0.93	0.50
C-Area Stream	1.04	.20
Thompson Run Stream	1.42	.14
Streets Run (Control Stream)	.29	.29

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–December 1967	March 1969
January–December 1968	January 1970

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2. Los Alamos Scientific Laboratory[3]
January–December 1969

University of California
Los Alamos, N. Mex.

As part of the environmental monitoring program at Los Alamos, measurements of beta radioactivity in airborne particulates and precipitation are made periodically. The samples have been taken on the roof of building TA-50 (about 1 3/4 miles southeast of the administration building) since March 1963.

Air monitoring

Airborne radioactive particulate matter is collected on 4-inch-diameter filters. The air sampling rate is 25.5 m^3/h. Air samples are ordinarily collected for 24-hour intervals during the work week, and weekend samples are collected for a 72-hour period.

The filters are counted for beta radioactivity 7 days after collection in a thin-window gas (methane) flow proportional counter with an overall efficiency of 50 percent for strontium-yttrium-90.

Precipitation monitoring

Collection is made in a 0.4 square meter rain collector which delivers 1 liter of water for each

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[3] Summarized from "Beta Radioactivity in Environmental Air and Precipitation at Los Alamos, New Mexico, for 1969" (LA-4388).

0.1 inch of precipitation. It has been found that this arrangement collected radioactivity even during relatively dry periods. By washing down the sides of the collector with 1 liter of distilled water, a suitable sample is obtained. Samples are taken daily on workdays. These "wash" samples, as well as any precipitation, are reduced in volume, dry-plated on 1-inch stainless-steel planchets, and counted in an automatic beta-particle system, employing a gas-flow proportional, alpha and beta chamber. A cosmic-ray umbrella with coincidence counter cancel provides a low background for the system. The counting efficiency is determined with a radiolead standard which emits 1.17 MeV beta particles.

Results

Average daily radioactivity concentrations for air collected are weighted for sample periods of more than 1 day. Average radioactivity concentrations for the precipitation collection are calculated from the total radioactivity collected during the month divided by the number of days in the month. Summary of air and precipitation data for January to December 1969 are summarized in table 4.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
1968	September 1969

Table 4. Beta radioactivity in air and precipitation, Los Alamos January–December 1969

Month 1969	Air (pCi/m³)			Precipitation (pCi/m²)			
	Maximum	Minimum	Average	Maximum	Minimum	Average	Total
January	0.11	<0.01	0.05	0.086	0.001	0.021	0.644
February	.17	.03	.08	.340	.003	.038	1.065
March	.27	.03	.08	.166	.003	.036	1.118
April	.38	.09	.20	2.237	.007	.243	7.304
May	.47	.06	.29	6.958	.030	.434	13.048
June	.49	.21	.37	3.723	.031	.666	19.980
July	.27	.06	.13	.969	.004	.173	5.301
August	.18	.04	.08	.518	.025	.119	3.699
September	.17	.03	.07	.274	.004	.080	2.407
October	.26	<.01	.10	.678	.008	.129	3.991
November	.17	.04	.06	.070	.004	.021	.624
December	.08	<.01	.05	.099	.002	.021	.640

3. Paducah Plant[4]
July–December 1969

Union Carbide Corporation
Paducah, Ky.

The Paducah Plant is a government-owned gaseous diffusion plant operated by the Nuclear Division of the Union Carbide Corporation for the Atomic Energy Commission. The diffusion plant processes large quantities of relatively pure uranium compounds. The uranium hexafluoride manufacturing plant, a former source of diffusion plant feed which was placed on standby in June of 1964, was reactivated in August 1968. Parts of the associated uranium metal foundry, usually on standby, are operated infrequently as the need arises. A decontamination and uranium recovery facility operates to prepare equipment for repair and to recover impure or scrap uranium materials. Depleted uranium metal is fabricated into shields, weights, ballasts, or other shapes on a nonroutine basis. The major sources of external penetrating radiation are the daughter products of uranium, thorium-234, and protactinium-234, which may be concentrated by uranium recovery processes or by uranium hexafluoride vaporization. The element uranium can be a physiological hazard only if allowed to enter the body. The chemical toxicity of the uranium processed at the Paducah Plant overshadows any probable biological effects of radiation from this element, thus making it comparable as a physiological hazard to lead, mercury, or other well-known heavy metals.

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[4] Summarized from "Environmental Concentrations of Radioactive Materials near the Paducah Plant—Report for the Year and the Second Half of 1969."

The uranium enrichment areas (Cascade) operate with a very low loss of material. Millions of pounds of uranium hexafluoride may be fed to, diffused in, and withdrawn from the cascade with the loss of only a few pounds per year. There is a slight loss of uranium to the atmosphere when diluent gases are purged from equipment units or from the cascade. Some uranium on cascade equipment replaced for maintenance or modification is removed in the decontamination facility.

Effluents from the uranium hexafluoride manufacturing plant are more significant than those of the diffusion cascade. The transfer of powdered uranium salts between the numerous processing reactors and intermediate storage facilities requires extensive use of vacuum or local exhaust systems. Various bag and pleated filter units are used to remove uranium from exhaust air. The product uranium hexafluoride is separated from entrained solids, excess fluorine, and diluent gases by a series of filters, cold condensers, and fluid bed absorbers. A small fraction of the input to this plant constituting a significant amount of uranium is not reacted to uranium hexafluoride and must be processed through uranium recovery at the decontamination facility. Beta radioactive uranium decay products which separate from the uranium hexafluoride at fluorination are also in this material flow.

The environmental monitoring program provides for continuously sampling the air at four stations around the plant perimeter fence, and at five stations located approximately 1 mile outside this fence (figure 2). Big and Little Bayou Creek waters are sampled continuously, and grab samples are collected at five locations in the Ohio River and at the mouth of the combined Bayou Creeks. In addition, gamma radiation readings are taken each month at each of the air sampling stations with a Geiger-Mueller type meter at a distance of 3 feet above ground level.

Basic standards

The radiation protection standards observed at the Paducah Plant for exposure to radiation and radioactive materials, both for the in-plant work environment of employees and for offsite exposure of the general population, are those contained in Appendix 0524 of the AEC manual. The standards specify that the radiation or radioactive materials outside a controlled area, and which have resulted from operations within that controlled area, shall be such that is it improbable that any individual may receive a dose of external radiation greater than 0.5 rem in any year and that the average exposure of a suitable population sample may not exceed one-third of this dose. To meet this standard, the average concentration of radionuclides in air or water beyond a controlled area should not exceed one-tenth of the maximum permitted for occupational exposure of 168 hours per week. For the purposes of such control, the concentrations of such radio-

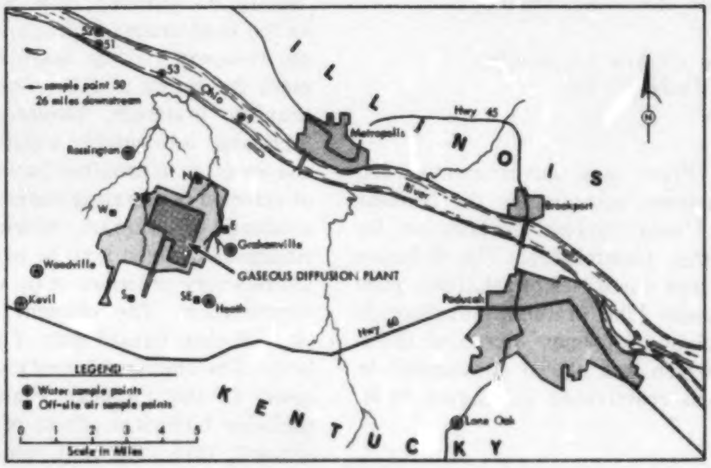

Figure 2. Sampling locations, Paducah Gaseous Diffusion Plant

nuclides in air or water may be averaged over periods of time up to 1 year.

Discussion

Data summarizing the environmental concentrations of radioactive materials in air and water and the gamma radiation levels in the vicinity of the Paducah Gaseous Diffusion Plant are presented in tables 5 through 9.

Table 5. Uranium concentrations in outdoor air samples, Paducah Plant, July–December 1969

Sample locations[a]	Number of samples	Uranium alpha radioactivity[b] (pCi/m³)		
		Maximum	Minimum[c]	Mean[d]
At plant perimeter fence:				
North	26	0.11	<0.02	0.03
East	26	.14	< .02	.03
South	26	.04	< .02	.01
West	26	.07	< .02	.02
All locations	104	0.14	<0.02	0.02
About 1 mile outside plant perimeter fence:				
North	26	0.04	<0.02	0.01
East	26	.06	< .02	.01
South	26	.05	< .02	.01
West	26	.03	< .02	.01
Southeast	26	.05	< .02	.01
All locations	130	0.06	<0.02	0.01

[a] See figure 2.

[b] As defined in NBS Handbook 69, paragraph 3.2, a microcurie of recently extracted normal uranium corresponds to 7.57 × 10^4 alpha dis/sec.

[c] The minimum detectable concentration of uranium in air is 0.02 pCi/m³.

[d] The AEC standard for natural uranium in air released to the environs beyond a controlled area is 2 pCi/m³.

Table 6. Beta radioactivity in outdoor air samples Paducah Plant, July–December 1969

Sample locations[a]	Number of samples	Beta radioactivity (pCi/m³)		
		Maximum	Minimum[b]	Mean[c]
At plant perimeter fence:				
North	26	3.9	<0.1	1.0
East	26	2.0	< .1	.50
South	26	.86	< .1	.27
West	26	1.9	< .1	.44
All locations	104	3.9	<0.1	0.50
About 1 mile outside plant perimeter fence:				
North	26	.59	<0.1	.21
East	26	.32	< .1	.14
South	26	.50	< .1	.19
West	26	.54	< .1	.22
Southeast	26	.50	< .1	.21
All locations	130	0.59	<0.1	0.19

[a] See figure 2.

[b] The minimum detectable amount of beta-particle emitters in air is 0.1 pCi/m³.

[c] The AEC standard, applicable to this table is 1 × 10^3 pCi/m³, which is the concentration limit of thorium-234, the daughter product of uranium-238. Insignificant amounts of other daughters are present in freshly refined uranium.

Air samples were collected continuously at each of the four stations at the plant perimeter fence and at five stations about 1 mile outside the plant. Air is filtered at 0.3 cfm through 2-inch diameter membrane filters which are replaced weekly and counted for alpha and beta radioactivity.

Table 7. Concentrations of uranium in water, Paducah Plant, July–December 1969

Sample locations[a]	Number of samples	Uranium[b] (pCi/liter)		
		Maximum	Minimum[c]	Mean[d]
Little Bayou 17	26	420	4	81
Big Bayou	26	21	<1	3
Mouth of Bayou 3 Creeks 21	6	1	<1	<1
Ohio River 9	6	<1	<1	<1
Composite of 50, 51, 52 and 53	6	<1	<1	<1

[a] See figure 2.

[b] As defined in NBS Handbook 69, paragraph 3.2, a microcurie of recently extracted normal uranium corresponds to 7.57 × 10^5 alpha dis/sec.

[c] The minimum detectable concentration of uranium in water is 1 pCi/liter.

[d] The AEC standard for natural uranium in air released to the environs beyond a controlled area is 2 pCi/m³.

Table 8. Concentration of beta-particle emitters in water, Paducah Plant, July–December 1969

Sample locations[a]	Number of samples	Beta-particle emitters (pCi/liter)		
		Maximum	Minimum[b]	Mean
Little Bayou 17	26	38,000	<100	2,100
Big Bayou 3	26	100	<100	<100
Mouth of Bayou Creeks 21	6	<100	<100	<100
Ohio River 9	6	<100	<100	<100
Composite of 50, 51, 52 and 53	6	<100	<100	<100

[a] See figure 2.

[b] The minmum detectable amount of beta-particle emitters in water is 100 pCi/liter.

[c] The AEC standard for the immediate daughter products of uranium in water released to the environs is 2 × 10^4 pCi/liter. An increase in beta radioactivity in water, occurring during February and March 1969, was determined to be due to technetium-99 from the recovery operation of cylinder-wash solutions. The AEC standard for technetium-99 in water beyond a controlled area is 2 × 10^5 pCi/liter.

The average alpha-particle count—interpreted as uranium, the most likely source of radioactivity—of the 104 and the 130 air samples collected during the first half of 1969 at the perimeter fence and 1 mile, respectively, were 1.0 percent and 0.5 percent for the July–December period and for the year 1969 were 1 percent and 0.5 percent of the AEC standard set for individuals residing in the vicinity of a controlled area. The average beta-particle count of these samples was 0.06 of the standard at the perimeter fence and 0.02 percent of the standard at 1 mile.

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Table 9. External gamma radiation levels Paducah, July–December 1969

Sample location[a]	Number of readings	Gamma radiation (mR/h)
At plant perimeter fence:		
North	5	0.02
East	5	.05
South	5	.02
West	5	.02
All locations	20	0.03
About 1 mile outside plant perimeter fence:		
North	5	0.02
East	5	.02
South	5	.02
West	5	.02
Southeast	5	.02
All locations	25	0.02

[a] See figure 2.

The average uranium analyses of weekly water samples collected continuously from Big and Little Bayou Creeks were 0.02 and 0.41 percent, respectively, of the AEC standard for water beyond a controlled area, during the second half of 1969; they were 0.03 and 0.33 percent, respectively, for the year 1969. The average of 11 grab samples taken in the mouth of the combined Bayou Creeks for the year of 1969 was less than 0.01 percent of the AEC standard, the identical figure for the mean analysis for the July–December period. The results of the uranium analyses for each of 11 grab samples collected at monthly intervals from the Ohio River below the plant was less than 0.01 percent of the AEC standard.

The concentration of beta-particle emitters in the Big and Little Bayou Creeks averaged less than 5 percent and 11 percent, respectively, of the AEC standard for the decay products of uranium–238 during July–December 1969 and less than 5 percent and 20 percent, respectively, for 1969. At the mouth of the combined Bayou Creeks, this average was less than 0.5 percent. The beta radioactivity of the Ohio River was below the standard during July–December 1969 and for the year averaged less than 0.5 percent of the standard for uranium–238 decay products.

External gamma radiation in the vicinity of the Paducah Plant averaged 0.02 mR/h at all sampling stations for July–December 1969, except for the east plant perimeter station, which had an average of 0.05 mR/h.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1968	July 1969
January–June 1969	April 1970

Reported Nuclear Detonations, August 1970

(Includes seismic signals from foreign test areas)

There were no nuclear detonations or seismic signals repored by the U. S. Atomic Energy Commission for August 1970.

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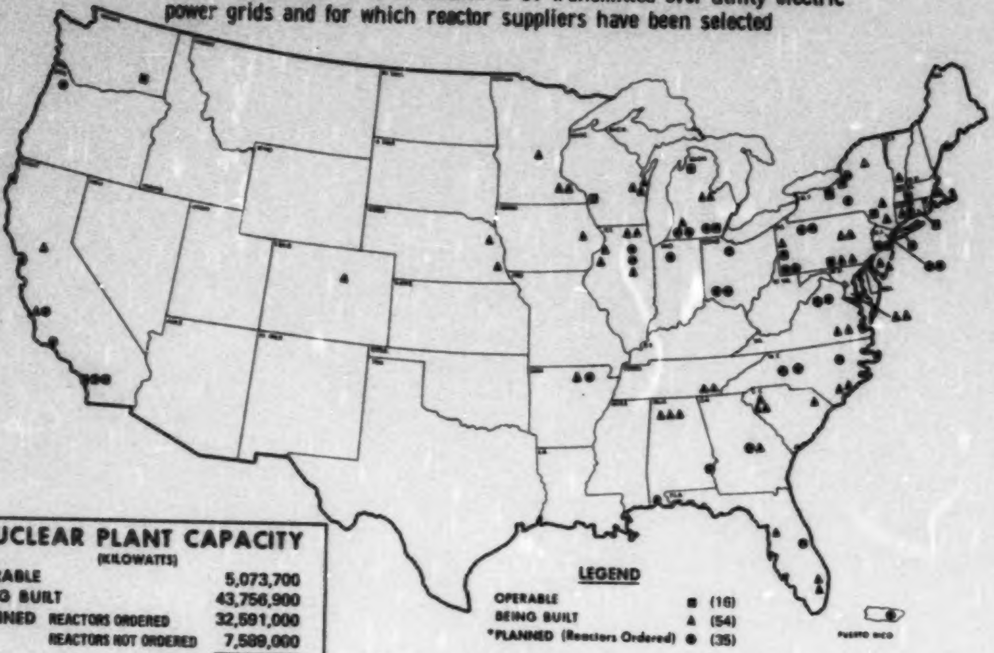
SITE	PLANT NAME	CAPACITY (Kilowatts)	UTILITY	INITIAL DESIGN POWER
ALABAMA				
Decatur	Browns Ferry Nuclear Power Plant: Unit 1	1,064,500	Tennessee Valley Authority	1971
Decatur	Browns Ferry Nuclear Power Plant: Unit 2	1,064,500	Tennessee Valley Authority	1972
Decatur	Browns Ferry Nuclear Power Plant: Unit 3	1,064,500	Tennessee Valley Authority	1972
Dothan	Joseph M. Farley Nuclear Plant	829,000	Alabama Power Co.	1975
ARKANSAS				
London	Arkansas Nuclear One: Unit 1	850,000	Arkansas Power & Light Co.	1973
London	Arkansas Nuclear One: Unit 2	950,000	Arkansas Power & Light Co.	1976
CALIFORNIA				
Humboldt Bay	Humbolt Bay Power Plant: Unit 3	68,500	Pacific Gas & Electric Co.	1963
San Clemente	San Onofre Nuclear Generating Station: Unit 1	430,000	So. Calif. Ed. & San Diego Gas & El. Co.	1967
San Clemente	San Onofre Nuclear Generating Station: Unit 2	1,140,000	So. Calif. Ed. & San Diego Gas & El. Co.	1975
San Clemente	San Onofre Nuclear Generating Station: Unit 3	1,140,000	So. Calif. Ed. & San Diego Gas & El. Co.	1977
Corral Canyon	Malibu Nuclear Plant: Unit1	462,000	L. A. Dept of Water & Power	1975
Diablo Canyon	Diablo Canyon Nuclear Power Plant: Unit 1	1,060,000	Pacific Gas & Electric Co.	1973
Diablo Canyon	Diablo Canyon Nuclear Power Plant: Unit 2	1,060,000	Pacific Gas & Electric Co.	1974
Clay Station	Rancho Seco Nuclear Generating Station	800,000	Sacramento Municipal Utility District	1972
COLORADO				
Platteville	Ft. St. Vrain Nuclear Generating Station	330,000	Public Service Co. of Colorado	1972
CONNECTICUT				
Haddam Neck	Haddam Neck Plant	575,000	Conn. Yankee Atomic Power Co.	1967
Waterford	Millstone Nuclear Power Station: Unit 1	652,100	Northeast Utilities	1970
Waterford	Millstone Nuclear Power Station: Unit 2	828,000	Northeast Utilities	1974
FLORIDA				
Turkey Point	Turkey Point Station: Unit 3	651,500	Florida Power & Light Co.	1971
Turkey Point	Turkey Point Station: Unit 4	651,500	Florida Power & Light Co.	1972
Red Level	Crystal River Plant: Unit 3	858,000	Florida Power Corp.	1972
Ft. Pierce	Hutchinson Island	800,000	Florida Power and Light Co.	1973
GEORGIA				
Baxley	Edwin I. Hatch Nuclear Plant: Unit 1	786,000	Georgia Power Co.	1973
Baxley	Edwin I. Hatch Nuclear Plant: Unit 2	786,000	Georgia Power Co.	1976
ILLINOIS				
Morris	Dresden Nuclear Power Station: Unit 1	200,000	Commonwealth Edison Co.	1960
Morris	Dresden Nuclear Power Station: Unit 2	800,000	Commonwealth Edison Co.	1970
Morris	Dresden Nuclear Power Station: Unit 3	800,000	Commonwealth Edison Co.	1970
Zion	Zion Nuclear Plant: Unit 1	1,050,000	Commonwealth Edison Co.	1971
Zion	Zion Nuclear Plant: Unit 2	1,050,000	Commonwealth Edison Co.	1973
Cordova	Quad-Cities Station: Unit 1	800,000	Comm. Ed. Co.–Ia.–Ill. Gas & Elec. Co	1971
Cordova	Quad-Cities Station: Unit 2	800,000	Comm. Ed. Co.–Ia.–Ill. Gas & Elec. Co.	1971
Seneca	LaSalle Co. Nuclear Station: Unit 1	1,100,000	Comm. Ed. Co.–Ia.–Ill. Gas & Elec. Co.	1975
Seneca	LaSalle Co. Nuclear Station: Unit 2	1,100,000	Comm. Ed. Co.–Ia.–Ill. Gas & Elec. Co.	1976
INDIANA				
Dunes Acres	Bailly Generating Station	660,000	Northern Indiana Public Service Co.	1976
IOWA				
Cedar Rapids	Duane Arnold Energy Center: Unit 1	545,000	Iowa Electric Light and Power Co.	1973
MAINE				
Wiscasset	Maine Yankee Atomic Power Plant	790,000	Maine Yankee Atomic Power Co.	1972
MARYLAND				
Lusby	Calvert Cliffs Nuclear Power Plant: Unit 1	800,000	Baltimore Gas and Electric Co.	1973
Lusby	Calvert Cliffs Nuclear Power Plant: Unit 2	800,000	Baltimore Gas and Electric Co.	1974
MASSACHUSETTS				
Rowe	Yankee Nuclear Power Station	175,000	Yankee Atomic Electric Co.	1961
Plymouth	Pilgrim Station	654,000	Boston Edison Co.	1971
MICHIGAN				
Big Rock Point	Big Rock Point Nuclear Plant	70,300	Consumers Power Co.	1963
South Haven	Palisades Nuclear Power Station	700,000	Consumers Power Co.	1970
Lagoona Beach	Enrico Fermi Atomic Power Plant: Unit 1	60,900	Detroit Edison Co.	1963
Lagoona Beach	Enrico Fermi Atomic Power Plant: Unit 2	1,123,000	Detroit Edison Co.	1974
Bridgman	Donald C. Cook Plant: Unit 1	1,054,000	Indiana & Michigan Electric Co.	1972
Bridgman	Donald C. Cook Plant: Unit 2	1,060,000	Indiana & Michigan Electric Co.	1973
Midland	Midland Nuclear Power Plant: Unit 1	492,000	Consumers Power Co.	1973
Midland	Midland Nuclear Power Plant: Unit 2	818,000	Consumers Power Co.	1974
MINNESOTA				
Monticello	Monticello Nuclear Generating Plant	545,000	Northern States Power Co.	1970
Red Wing	Prairie Island Nuclear Generating Plant: Unit 1	530,000	Northern States Power Co.	1972
Red Wing	Prairie Island Nuclear Generating Plant: Unit 2	530,000	Northern States Power Co.	1974
NEBRASKA				
Fort Calhoun	Ft. Calhoun Station: Unit 1	457,400	Omaha Public Power District	1972
Brownville	Cooper Nuclear Station	778,000	Consumers Public Power District and Iowa Power and Light Co.	1972
NEW JERSEY				
Toms River	Oyster Creek Nuclear Power Plant: Unit 1	530,000	Jersey Central Power & Light Co.	1969
Lacey Township	Forked River Generating Station: Unit 1	1,129,000	Jersey Central Power & Light Co.	1975
Salem	Salem Nuclear Generating Station: Unit 1	1,050,000	Public Service Electric and Gas, N. J.	1972
Salem	Salem Nuclear Generating Station: Unit 2	1,050,000	Public Service Electric and Gas, N. J.	1973
Newbold Island	Newbold Nuclear Generating Station: Unit 1	1,068,000	Public Service Electric and Gas, N. J.	1975
Newbold Island	Newbold Nuclear Generating Station: Unit 2	1,068,000	Public Service Electric and Gas, N. J.	1977
NEW YORK				
Indian Point	Indian Point Station: Unit 1	265,000	Consolidated Edison Co.	1962
Indian Point	Indian Point Station: Unit 2	873,000	Consolidated Edison Co.	1971
Indian Point	Indian Point Station: Unit 3	965,000	Consolidated Edison Co.	1973
Scriba	Nine Mile Point Nuclear Station	500,000	Niagara Mohawk Power Co.	1968
Rochester	R. E. Ginna Nuclear Power Plant: Unit 1	420,000	Rochester Gas & Electric Co.	1970
Brookhaven	Shoreham Nuclear Power Station	819,000	Long Island Lighting Co.	1975
Lansing	Bell Station	838,000	New York State Electric & Gas Co.	1978
Verplanck	Verplanck: Unit 1	1,115,000	Consolidated Edison Co.	1977
Scriba	James A. Fitzpatrick Nuclear Power Plant	821,000	Power Authority of State of N.Y.	1973
NORTH CAROLINA				
Southport	Brunswick Steam Electric Plant: Unit 1	821,000	Carolina Power and Light Co.	1975
Southport	Brunswick Steam Electric Plant: Unit 2	821,000	Carolina Power and Light Co.	1976
*		821,000	Carolina Power and Light Co.	—
Cowans Ford Dam	Wm. B. McGuire Nuclear Station: Unit 1	1,150,000	Duke Power Co.	1976
Cowans Ford Dam	Wm. B. McGuire Nuclear Station: Unit 2	1,150,000	Duke Power Co.	1977
OHIO				
Oak Harbor	Davis-Besse Nuclear Power Station	872,000	Toledo Edison-Cleveland Electric Illuminating Co.	1974
Moscow	Wm. H. Zimmer Nuclear Power Station: Unit 1	810,000	Cincinnati Gas & Electric Co.	1974
Moscow	Wm. H. Zimmer Nuclear Power Station: Unit 2	810,000	Cincinnati Gas & Electric Co.	1975
OREGON				
Rainier	Trojan Station	1,106,000	Portland General Electric Co.	1974
PENNSYLVANIA				
Peach Bottom	Peach Bottom Atomic Power Station: Unit 1	40,000	Philadelphia Electric Co.	1967
Peach Bottom	Peach Bottom Atomic Power Station: Unit 2	1,065,000	Philadelphia Electric Co.	1971
Peach Bottom	Peach Bottom Atomic Power Station: Unit 3	1,065,000	Philadelphia Electric Co.	1973
Pottstown	Limerick Generating Station: Unit 1	1,065,000	Philadelphia Electric Co.	1976
Pottstown	Limerick Generating Station: Unit 2	1,065,000	Philadelphia Electric Co.	1977
Shippingport	Shippingport Atomic Power Station: Unit 1	90,000	Duquesne Light Co.	1957
Shippingport	Beaver Valley Power Station: Unit 1	847,000	Duquesne Light Co.–Ohio Edison Co.	1973
Middletown	Three Mile Island Nuclear Station: Unit 1	810,000	Metropolitan Edison Co.	1971
Middletown	Three Mile Island Nuclear Station: Unit 2	810,000	Jersey Central Power & Light Co.	1973
*	—	1,052,000	Pennsylvania Power and Light	1977
*	—	1,052,000	Pennsylvania Power and Light	1979
SOUTH CAROLINA				
Hartsville	H. B. Robinson S. E. Plant: Unit 2	700,000	Carolina Power & Light Co.	1970
Seneca	Oconee Nuclear Station: Unit 1	841,000	Duke Power Co.	1971
Seneca	Oconee Nuclear Station: Unit 2	886,000	Duke Power Co.	1972
Seneca	Oconee Nuclear Station: Unit 3	886,000	Duke Power Co.	1973
TENNESSEE				
Daisy	Sequoyah Nuclear Power Plant: Unit 1	1,124,000	Tennessee Valley Authority	1973
Daisy	Sequoyah Nuclear Power Plant: Unit 2	1,124,000	Tennessee Valley Authority	1974
VERMONT				
Vernon	Vermont Yankee Generating Station	513,900	Vermont Yankee Nuclear Power Corp.-Green Mt. Power Corp.	1971
VIRGINIA				
Gravel Neck	Surry Power Station: Unit 1	780,000	Virginia Electric & Power Co.	1971
Gravel Neck	Surry Power Station: Unit 2	780,000	Virginia Electric & Power Co.	1972
Mineral	North Anna Power Station: Unit 1	845,000	Virginia Electric & Power Co.	1974
Mineral	North Anna Power Station: Unit 2	845,000	Vrignia Electric & Power Co.	1975
WASHINGTON				
Richland	N-Reactor/WPPSS Steam	790,000	Washington Public Power Supply System	1966
WISCONSIN				
Genoa	LaCrosse Boiling Water Reactor	50,000	Dairyland Power Cooperative	1969
Two Creeks	Point Beach Nuclear Plant: Unit 1	497,000	Wisconsin Michigan Power Co.	1970
Two Creeks	Point Beach Nuclear Plant: Unit 2	497,000	Wisconsin Michigan Power Co.	1971
Carlton	Kewaunee Nuclear Power Plant: Unit 1	527,000	Wisconsin Public Service Co.	1972
PUERTO RICO				
Central Aguirre	Aguirre Nuclear Power Plant	583,000	Puerto Rico Water Resources Authority	1976

* Site not selected.

Figure 1. Nuclear Power Plants in the United States

NUCLEAR POWER PLANTS IN THE UNITED STATES

The nuclear power plants included in this map are ones whose power is being transmitted or is scheduled to be transmitted over utility electric power grids and for which reactor suppliers have been selected



NUCLEAR PLANT CAPACITY

(KILOWATTS)

OPERABLE		5,073,700
BEING BUILT		43,756,900
PLANNED	REACTORS ORDERED	32,591,000
	REACTORS NOT ORDERED	7,589,000
	TOTAL	89,010,600

ELECTRIC UTILITY CAPACITY BY CONVENTIONAL MEANS AS OF APRIL 30, 1970: 313,884,808 KILOWATTS

LEGEND

OPERABLE	■	(16)
BEING BUILT	▲	(54)
*PLANNED (Reactors Ordered)	●	(35)

*8 more plants have been announced for which reactors have not yet been ordered.

U.S. Atomic Energy Commission
June 30, 1970

Figure 1. Nuclear Power Plants in the United States—Continued

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SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

TRITIUM IN STREAMS IN THE UNITED STATES, 1961–1968. *T. A. Wyerman, R. K. Farmsworth,* and *G. L. Stewart. Radiological Health Data and Reports, Vol. 11, September 1970,* pp. 421–439.

As part of its program of water resources investigations, the U.S. Geological Survey. has been analyzing the tritium content of stream water since the early 1960's. The results of this sampling program for 20 streams in the conterminous United States and Alaska are tabulated along with relevant stream discharge data. The data show the effect on stream tritium concentration caused principally by thermonuclear detonations, and also seasonal, latitudinal, and continental effects.

KEYWORDS: Continental United States, stream discharge, tritium, water

NATURAL ENVIRONMENTAL RADIOACTIVITY IN SOUTH FLORIDA SANDS AND SOILS, FEBRUARY–JUNE 1968. *Douglas H. Keefer* and *Maxwell Dauer. Radiological Health Data and Reports, Vol. 11, September 1970,* pp. 441–448.

An investigation of the naturally occurring gamma-emitting radionuclides present in selected sands and soils of south Florida was conducted. Although the primary interest was in the natural environmental radioactivity from uranium-238, radium-226, thorium-232, and potassium-49, the concentrations of five fission products were also determined to minimize the error in computing the concentrations of the four naturally occurring radionuclides. The determination of these nine radionuclides in 45 environmental samples was performed by the linear least-squares method of analysis utilizing a computer.

KEYWORDS: Florida, potassium-40, radium-226, sands, soils, thorium-232, uranium-238

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